

Identified charged hadron production in Cu+Cu at $\sqrt{s_{NN}} = 22.5$ and 62.4 GeV in PHENIX

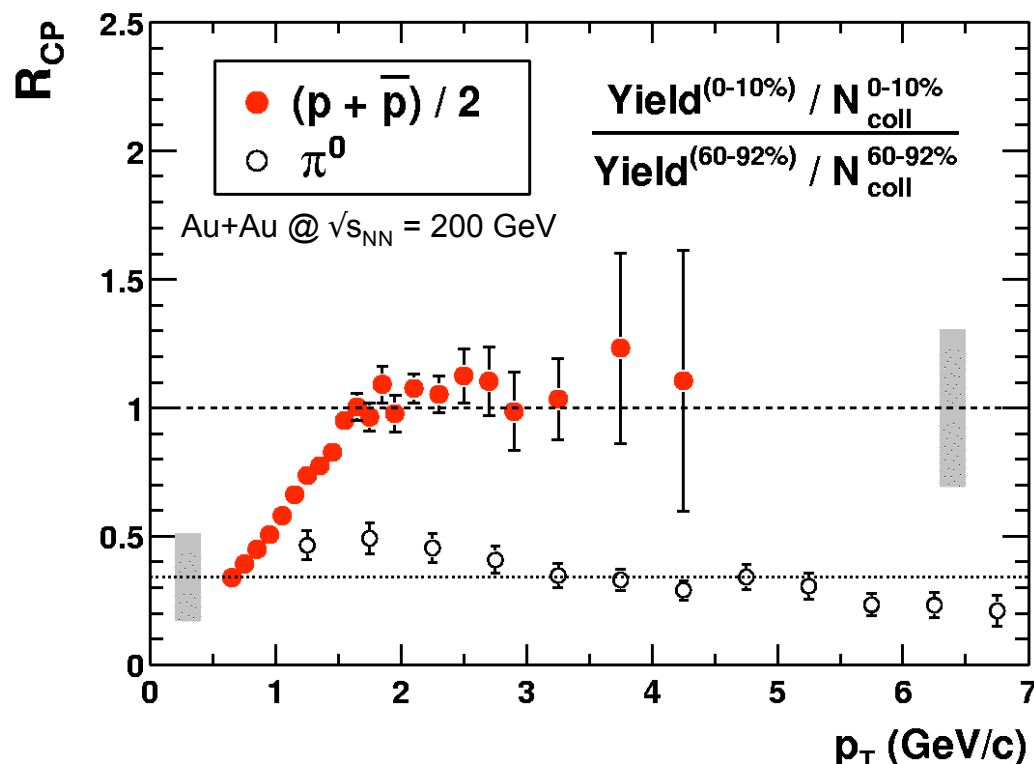
Tatsuya Chujo
for the PHENIX collaboration



Introduction

~ Baryon Anomaly at RHIC ~

PHENIX: PRL 91, 172301 (2003), PRC 69, 034909 (2004)



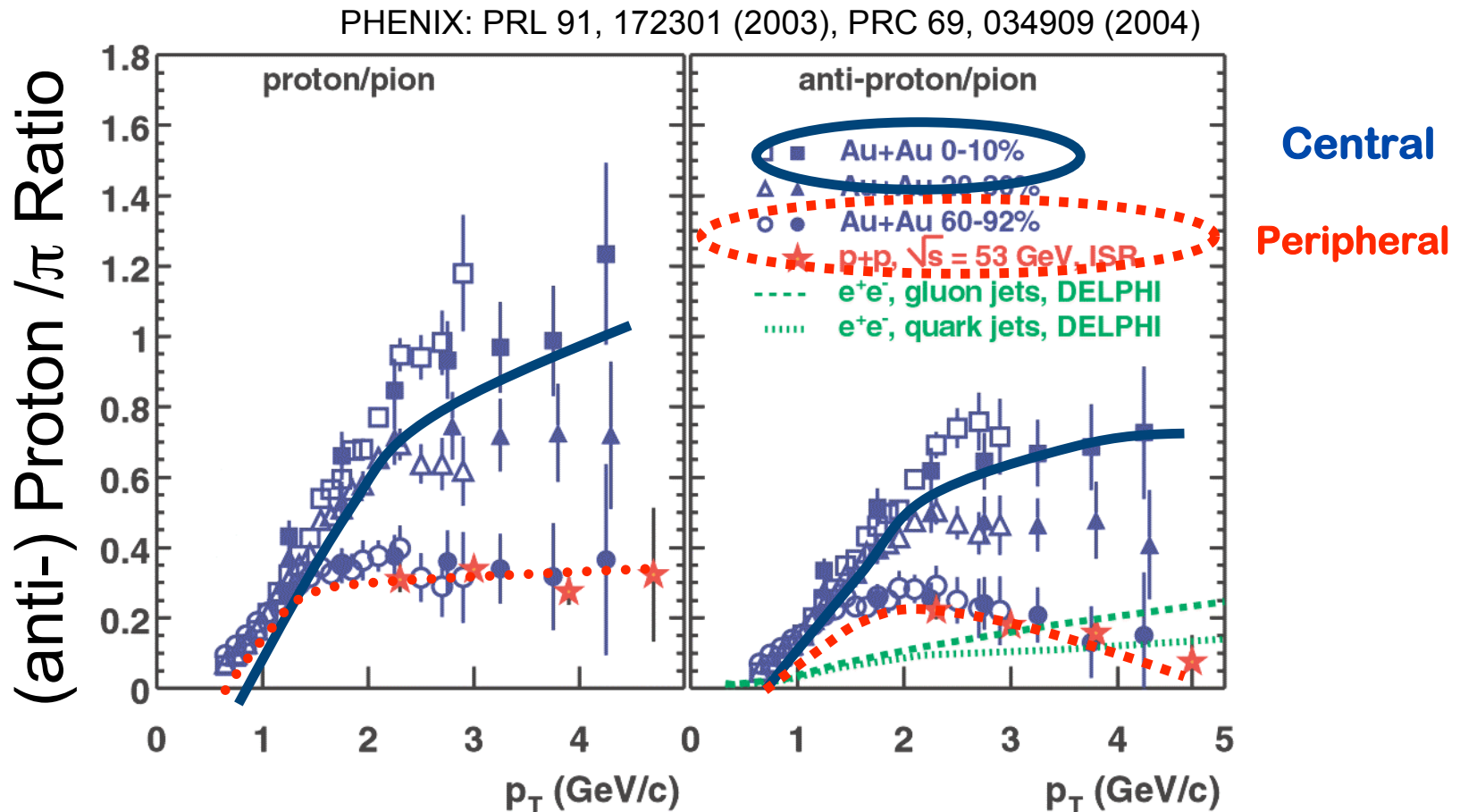
- In Au+Au $\sqrt{s_{NN}} = 200$ GeV central collisions:
 - Pions: Strong suppression of yields above $p_T \sim 2$ GeV/c, due to jet quenching effect.
 - Protons: No suppression for at intermediate p_T (2-5 GeV/c).
- **Called “Baryon anomaly at RHIC”.**
- **Quark recombination models** reproduce the data qualitatively.

Nuclear Modification Factor

$$R_{AA}(p_T) = \frac{\text{yield}(AuAu) / N_{\text{coll}}}{\text{yield}(pp)} \sim R_{CP}$$

p/π ratios in Au+Au 200 GeV

More (anti) baryons than pions at moderate p_T (2-5 GeV/c).
Does not look like vacuum jet fragmentation.

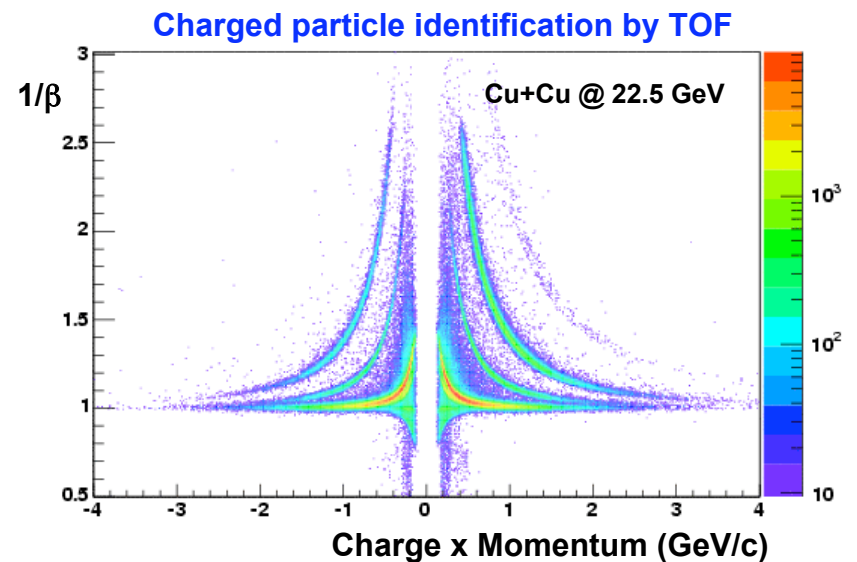
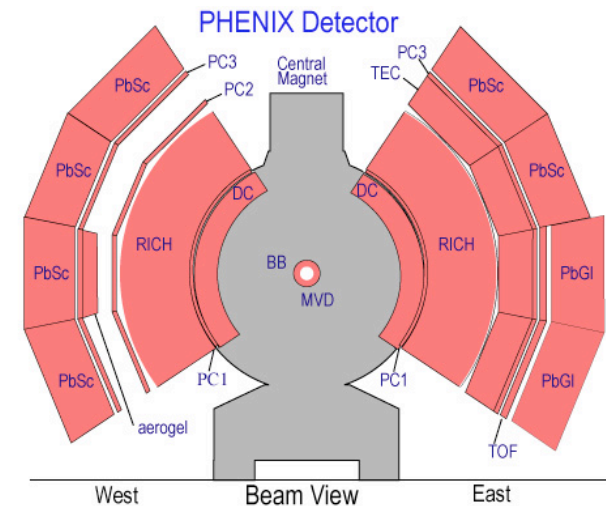


Where is the onset of the baryon anomaly at RHIC?

→ New Cu+Cu data at lower $\sqrt{s_{NN}}$ may give an answer...

Data Analysis

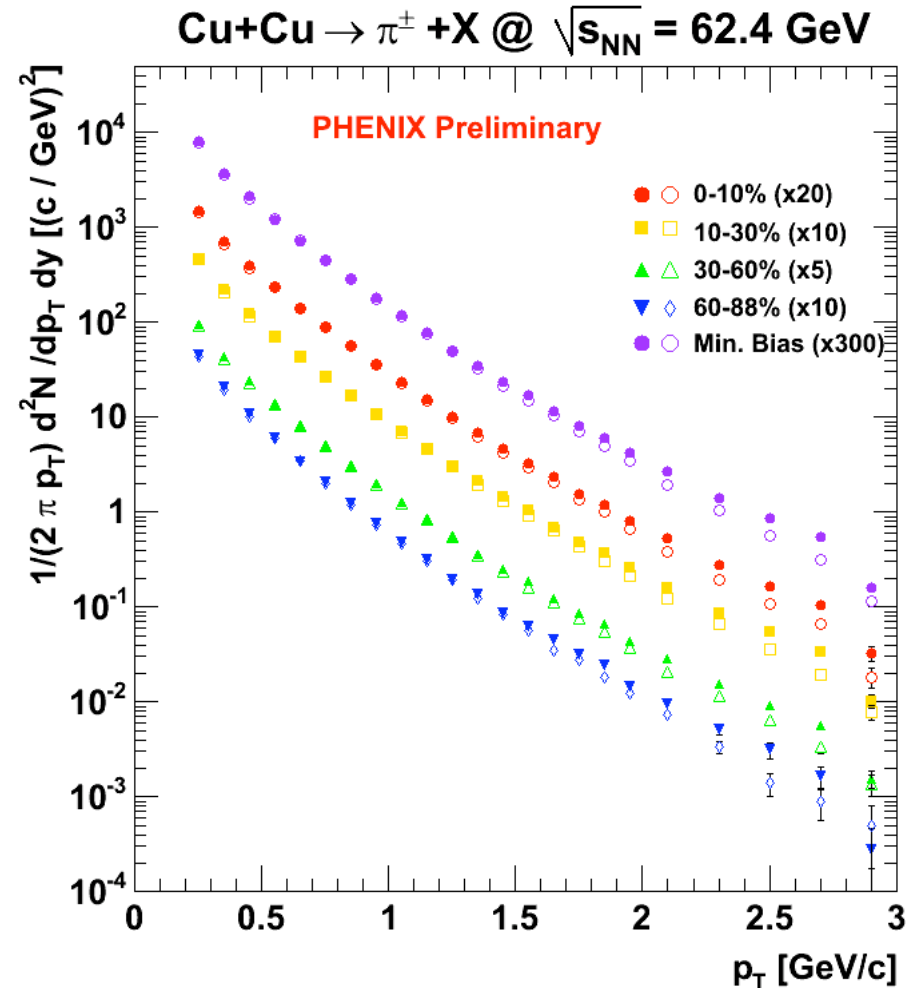
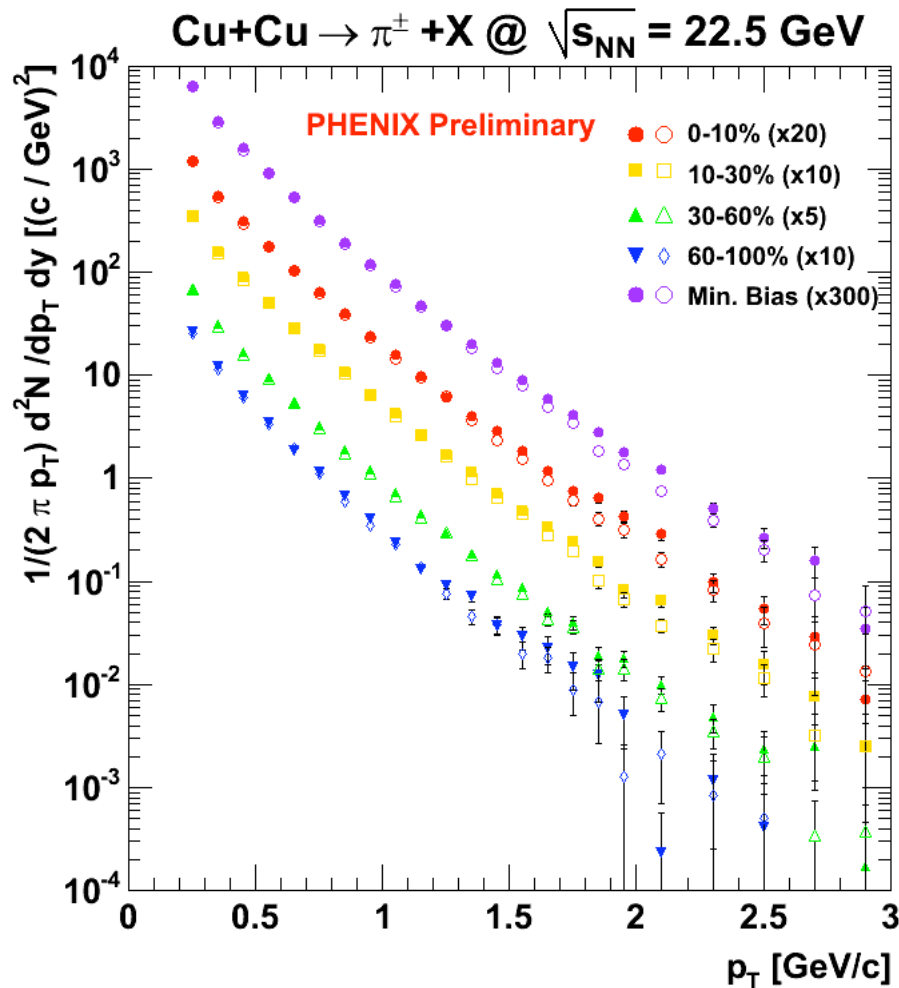
- **Data set:**
 - RHIC Run-5 (2005), measured by the PHENIX experiment.
 - **Cu+Cu at 22.5 GeV.**
 - **Cu+Cu at 62.4 GeV.**
- **Detectors:**
 - Drift Chamber, PC1, BBC and TOF for PID charged analysis.
- **Centrality:**
 - Subdivided minimum bias triggered events, based on BBC charge (62 GeV), or the number of PC1 hit (22 GeV).
- **Corrections:**
 - Geometrical acceptance, in flight decay.
 - NOTE: No weak decay feed-down correction applied.



Results

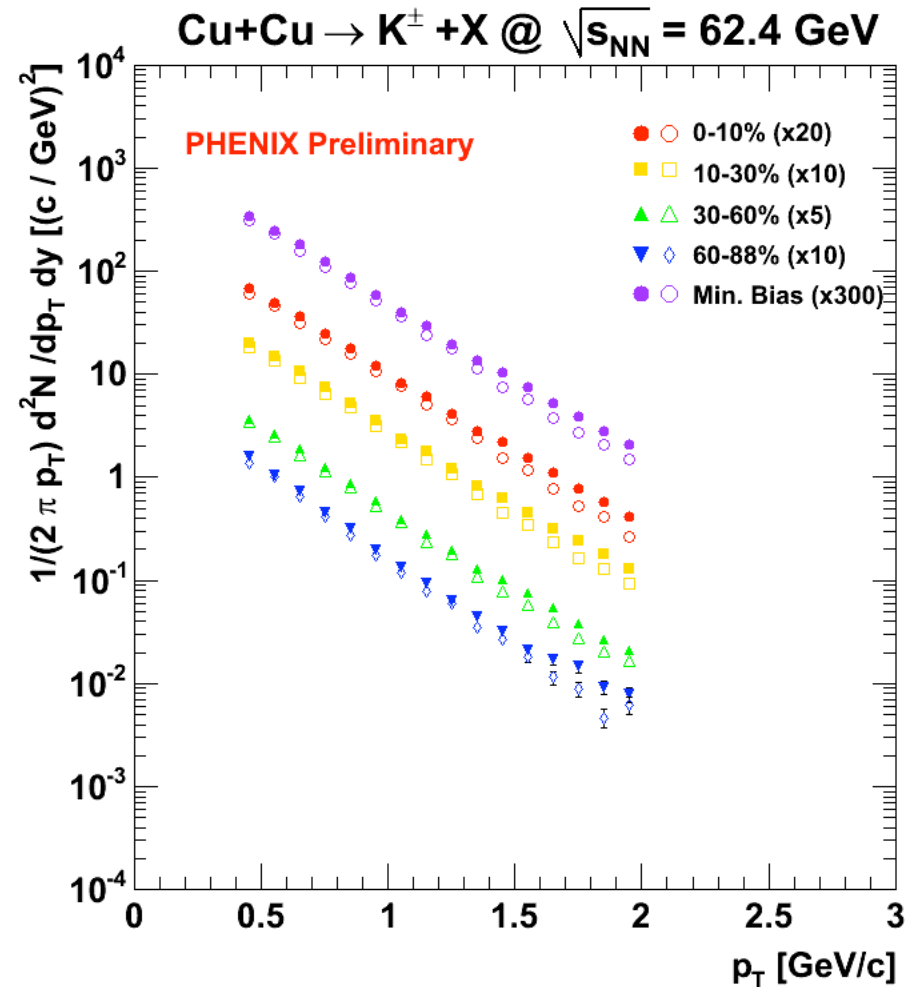
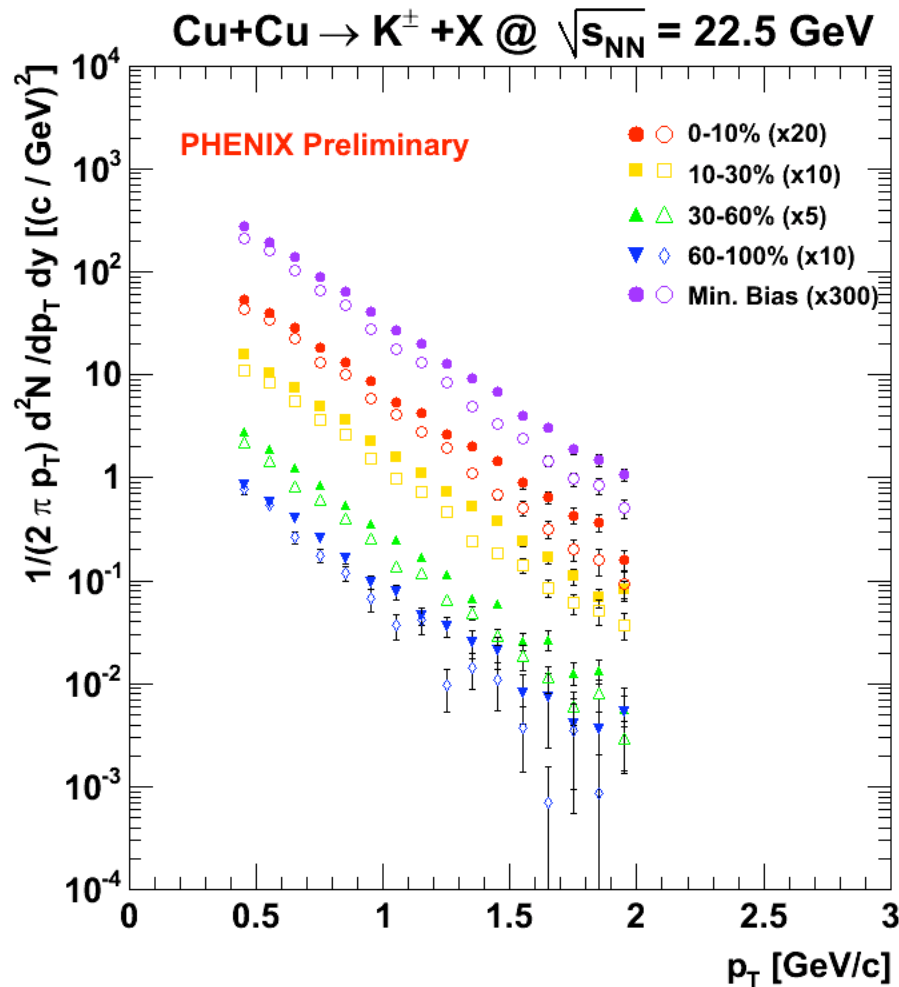
1. p_T spectra in Cu+Cu at $\sqrt{s_{NN}} = 22.5$ and 62.4 GeV.
2. p/π^+ and \bar{p}/π^- ratios vs. p_T .
3. Nuclear modification factor: R_{AA} .

p_T spectra for pions



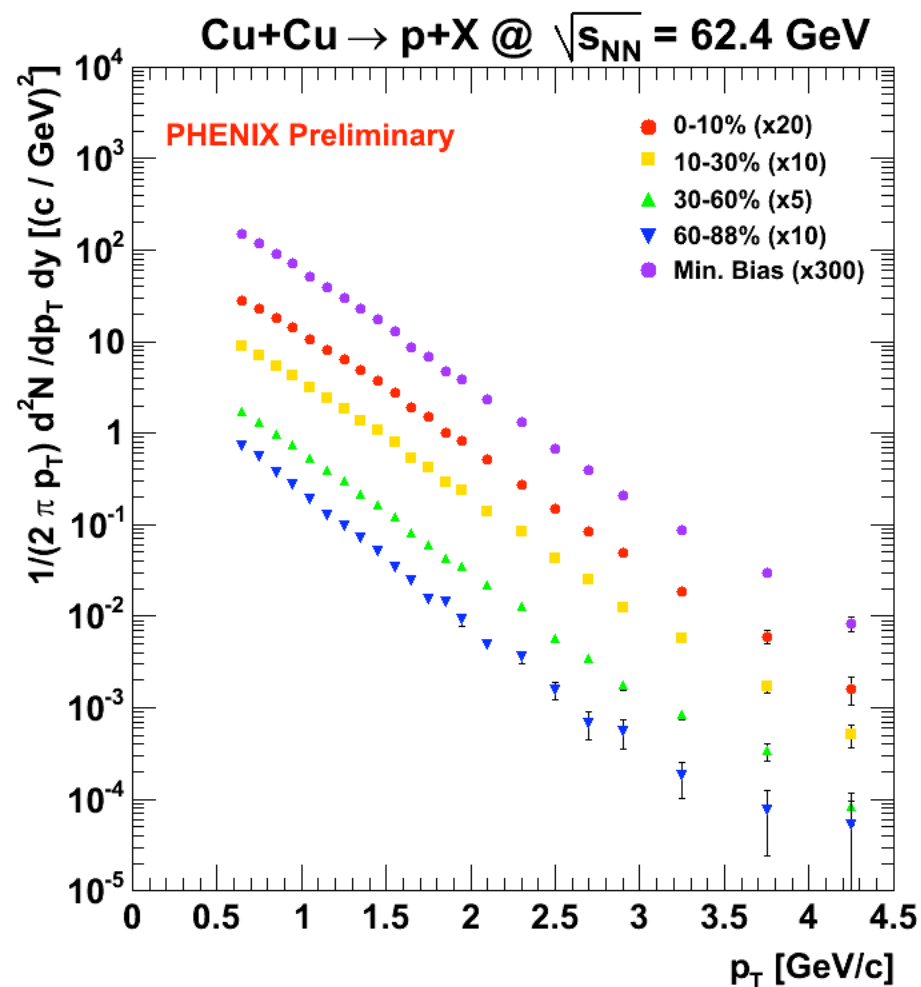
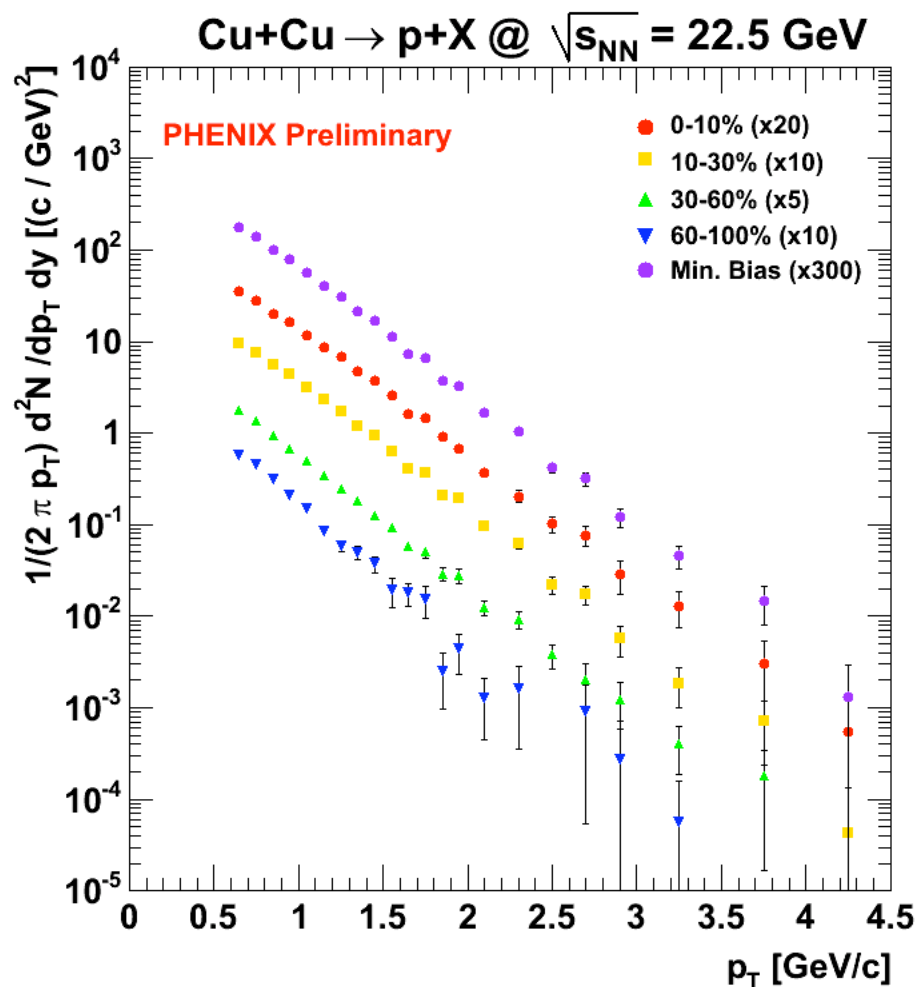
Filled symbols : π^+
Open symbols : π^-

p_T spectra for kaons



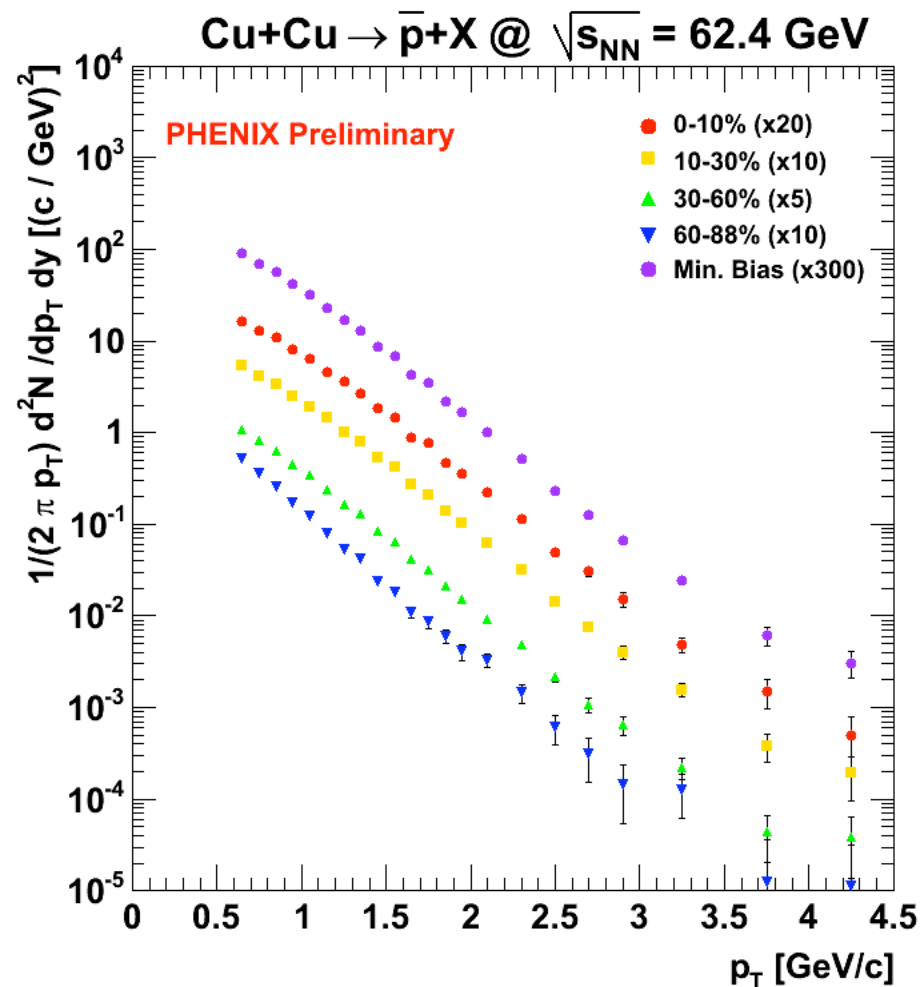
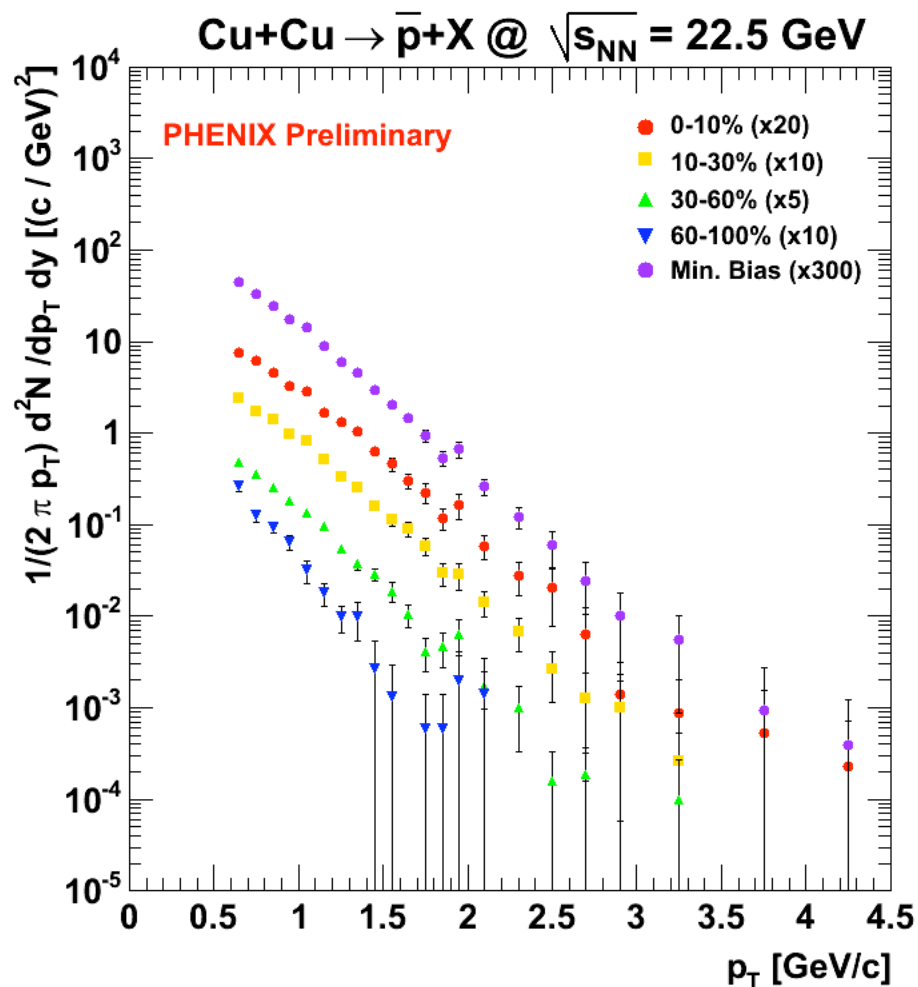
Filled symbols : K^+
Open symbols : K^-

p_T spectra for protons



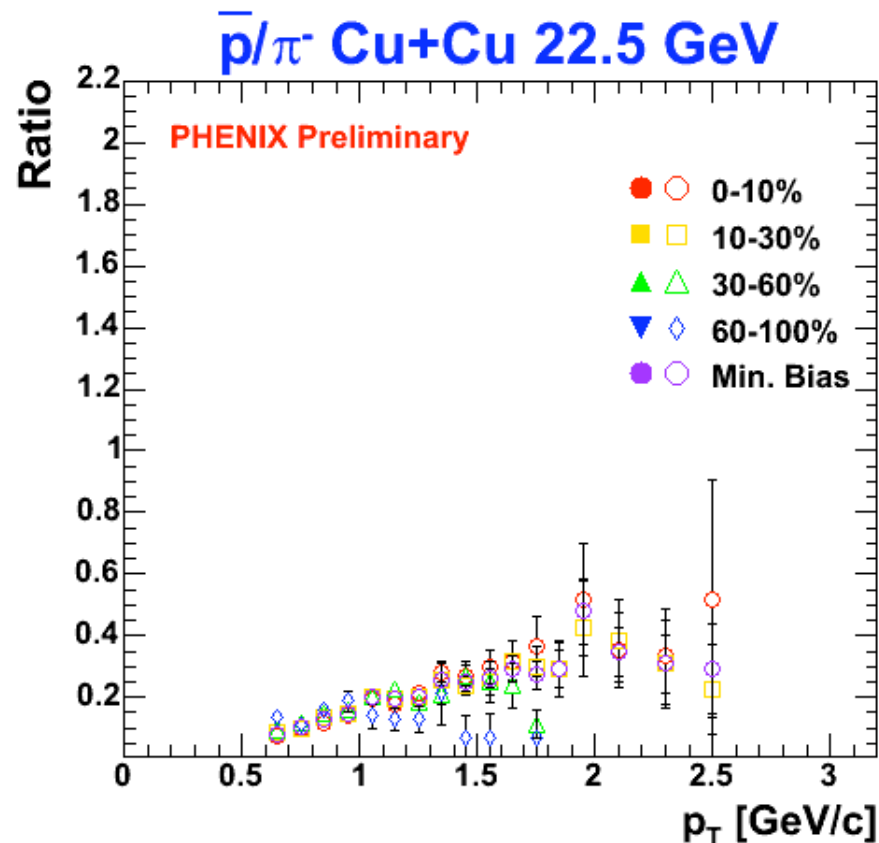
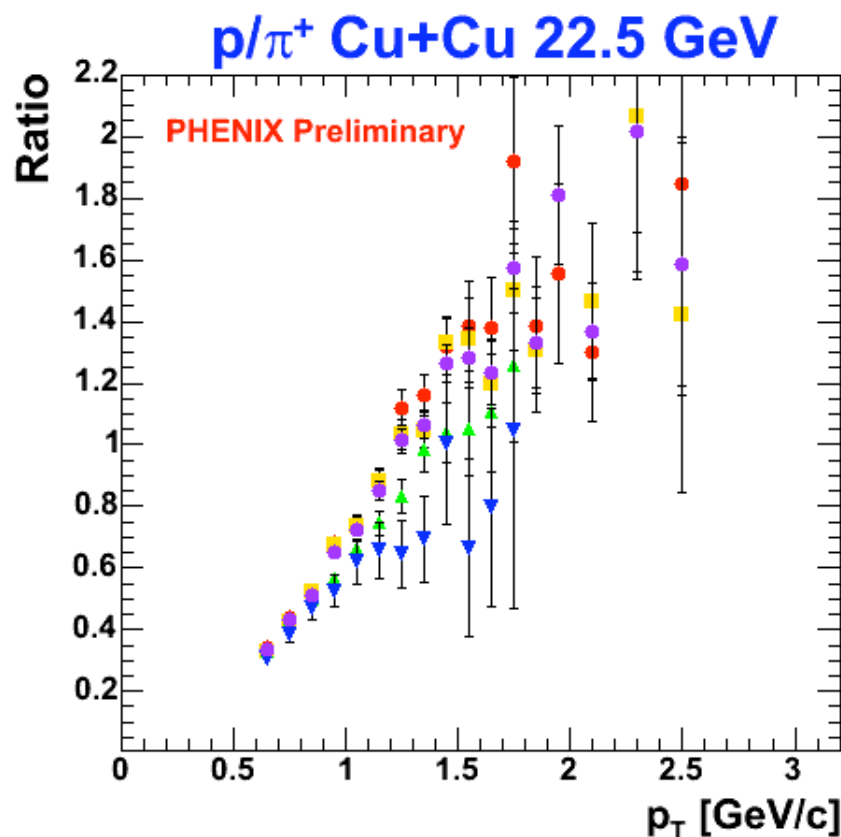
* No weak decay feed-down correction applied

p_T spectra for antiprotons



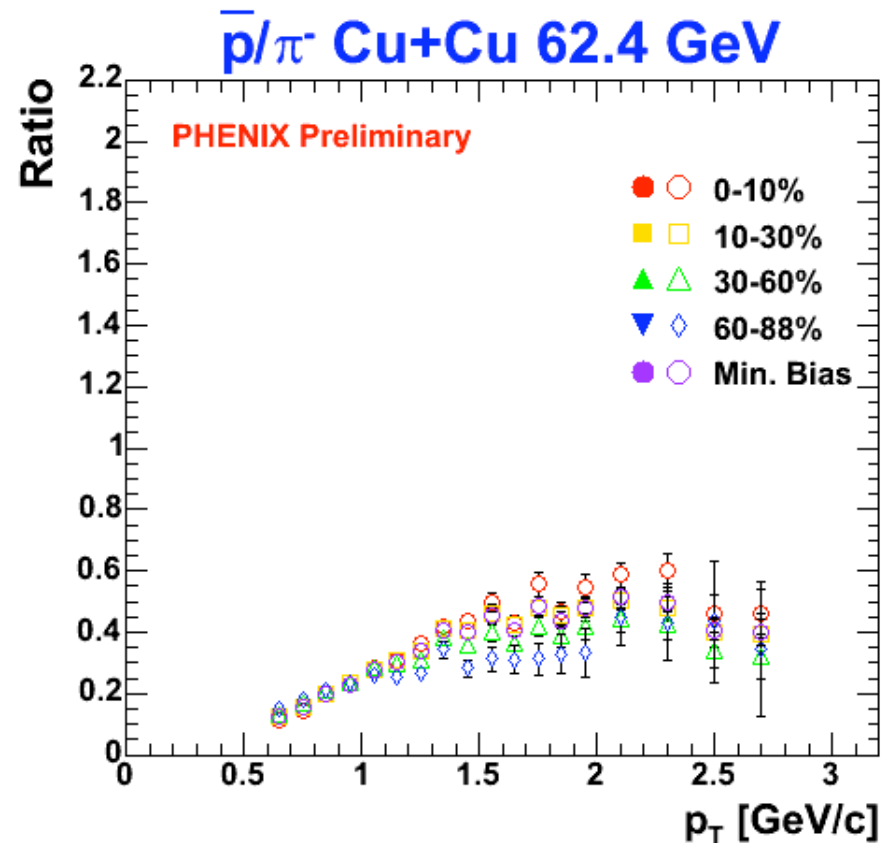
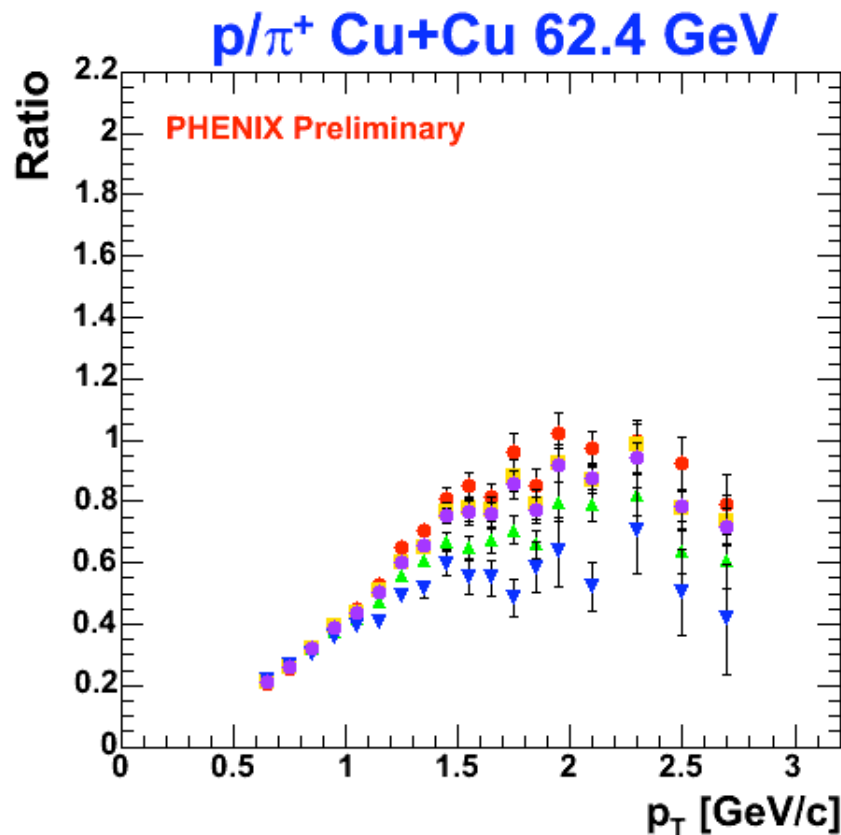
* No weak decay feed-down correction applied

p/π in Cu+Cu 22.5 GeV



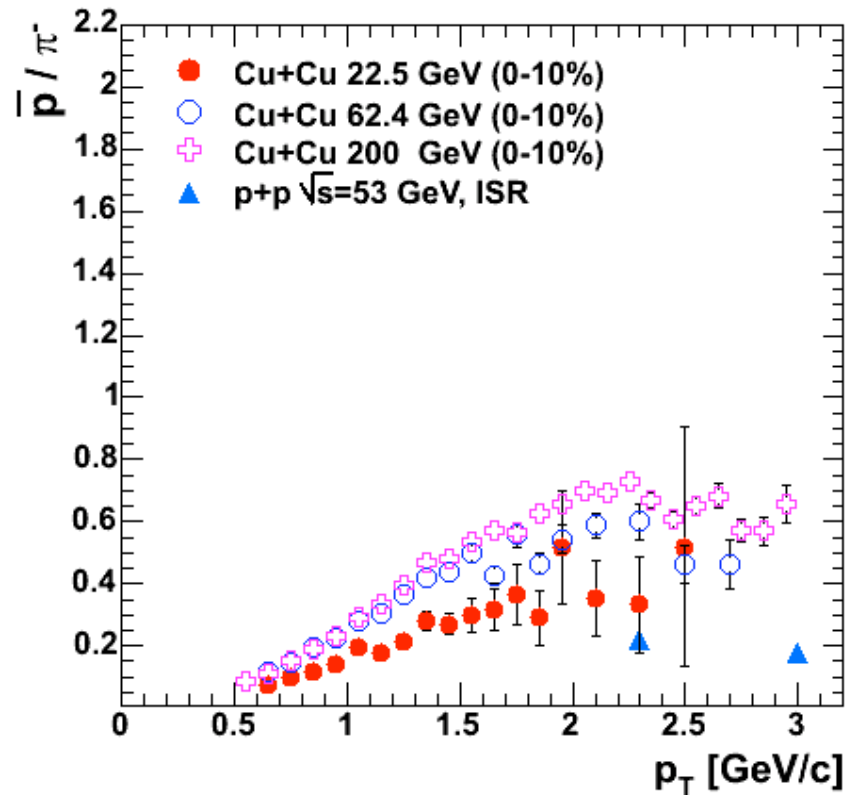
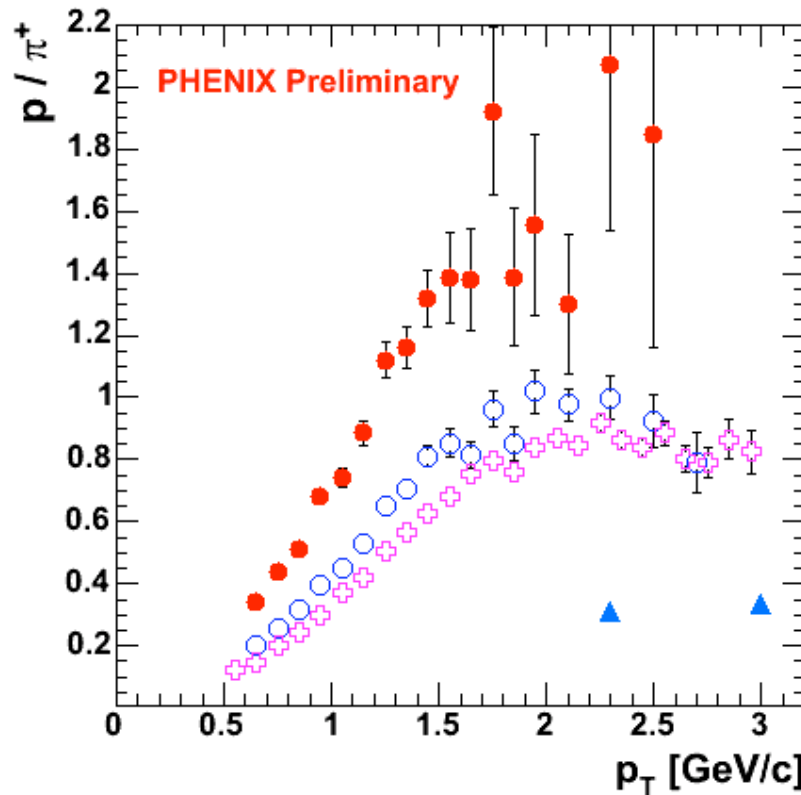
- **Larger p/π^+ ratios** than those in Au+Au 200 GeV (0.5 @ $p_T = 1.5$ GeV).
 - Affected by the spectator protons (not produced protons) at lower $\sqrt{s_{NN}}$.
- **\bar{p}/π^- ratios are $\sim 0.3-0.4$ at $p_T = 2$ GeV/c**, which is close to the fragmentation expectations in p+p.
 - **Almost no centrality dependence.**

p/π in Cu+Cu 62.4 GeV



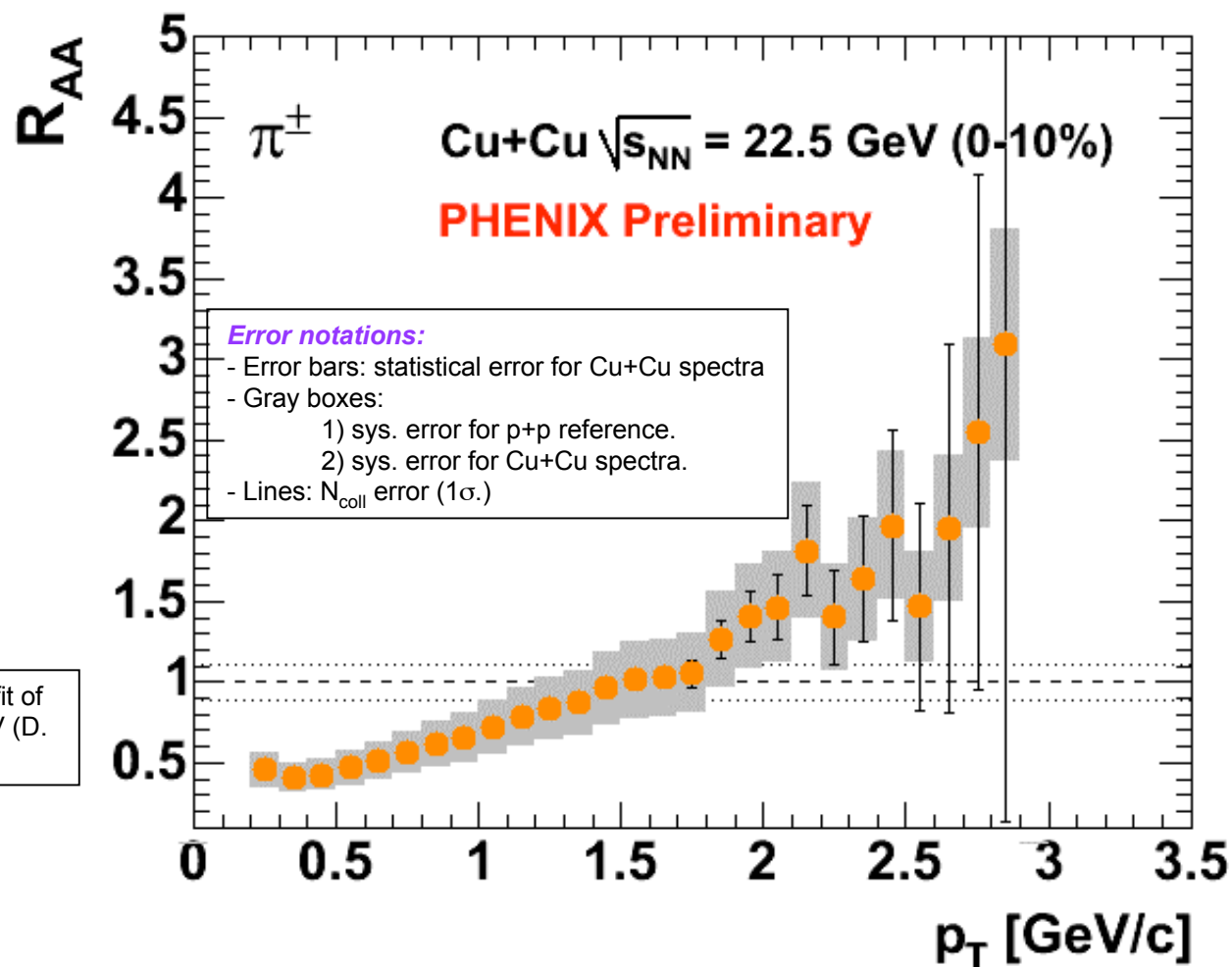
- p/π^+ ratios are reduced, compared to those in Cu+Cu 22 GeV.
- \bar{p}/π^- ratio in most central collisions reaches $R \sim 0.6$ at $p_T = 2$ GeV/c.
 - Centrality dependence is seen.
 - Peripheral \bar{p}/π^- : consistent with p+p value.

Beam energy dep. in Cu+Cu



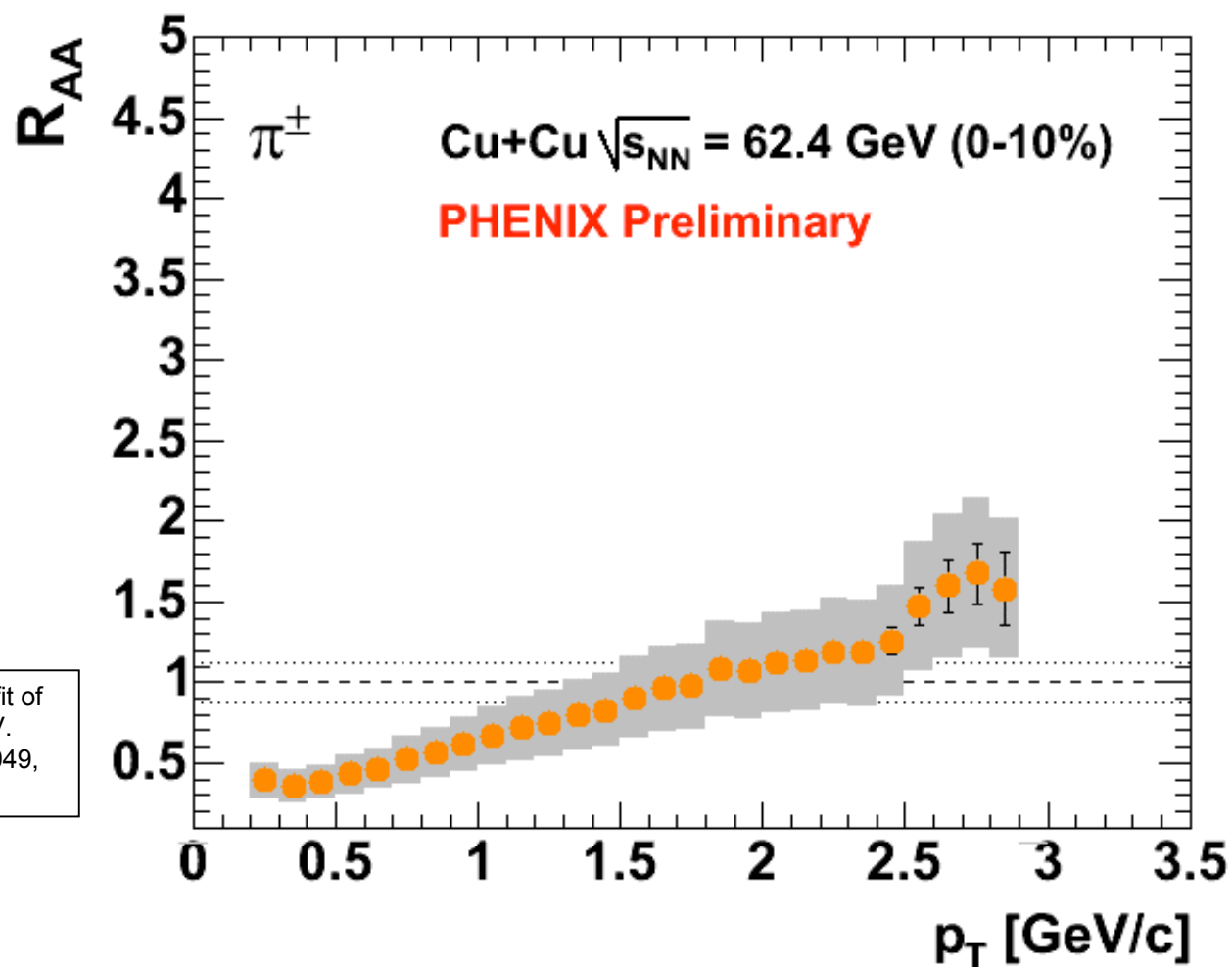
- **p/π^+ ratio** : decreasing as a function of \sqrt{s}_{NN} .
- **\bar{p}/π^- ratio** : increasing as a function \sqrt{s}_{NN} .
 - Cu+Cu 22.5 GeV central data reaches the p+p values.
 - Cu+Cu 62.4 GeV central data is higher than that in 22.5 GeV.

R_{AA} for pions (22 GeV)



- p+p reference: global fit of pion data at $\sqrt{s} \sim 22$ GeV in p+p.
- R_{AA} is ~ 1.5 at $p_T = 2$ GeV/c, **no suppression**.

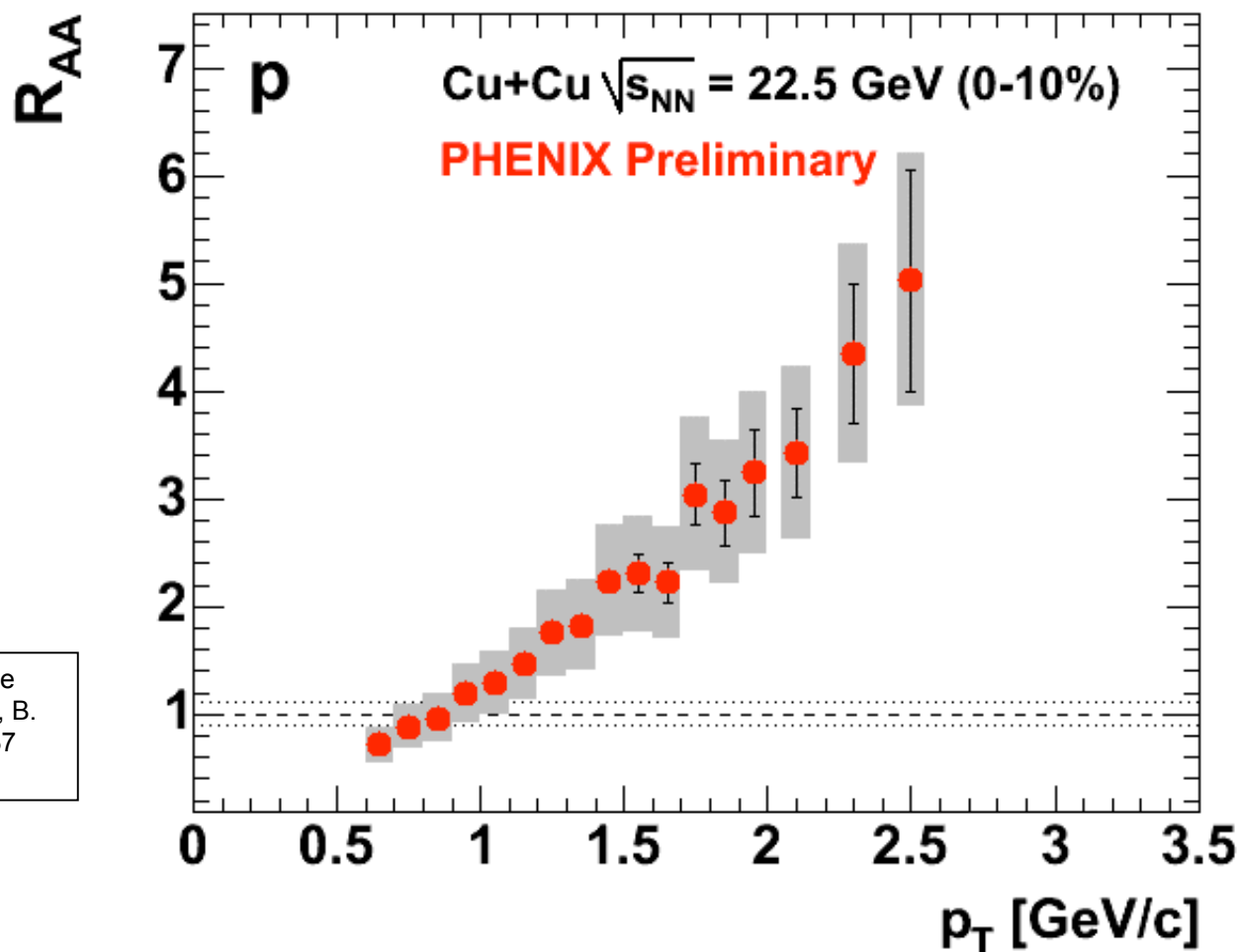
R_{AA} for pions (62 GeV)



- p+p reference: global fit of pion data at $\sqrt{s} \sim 62$ GeV.
- nucl-ex/ nucl-ex/0411049, D. d'Enterria.

- Similar, might be slightly smaller than that in 22 GeV.

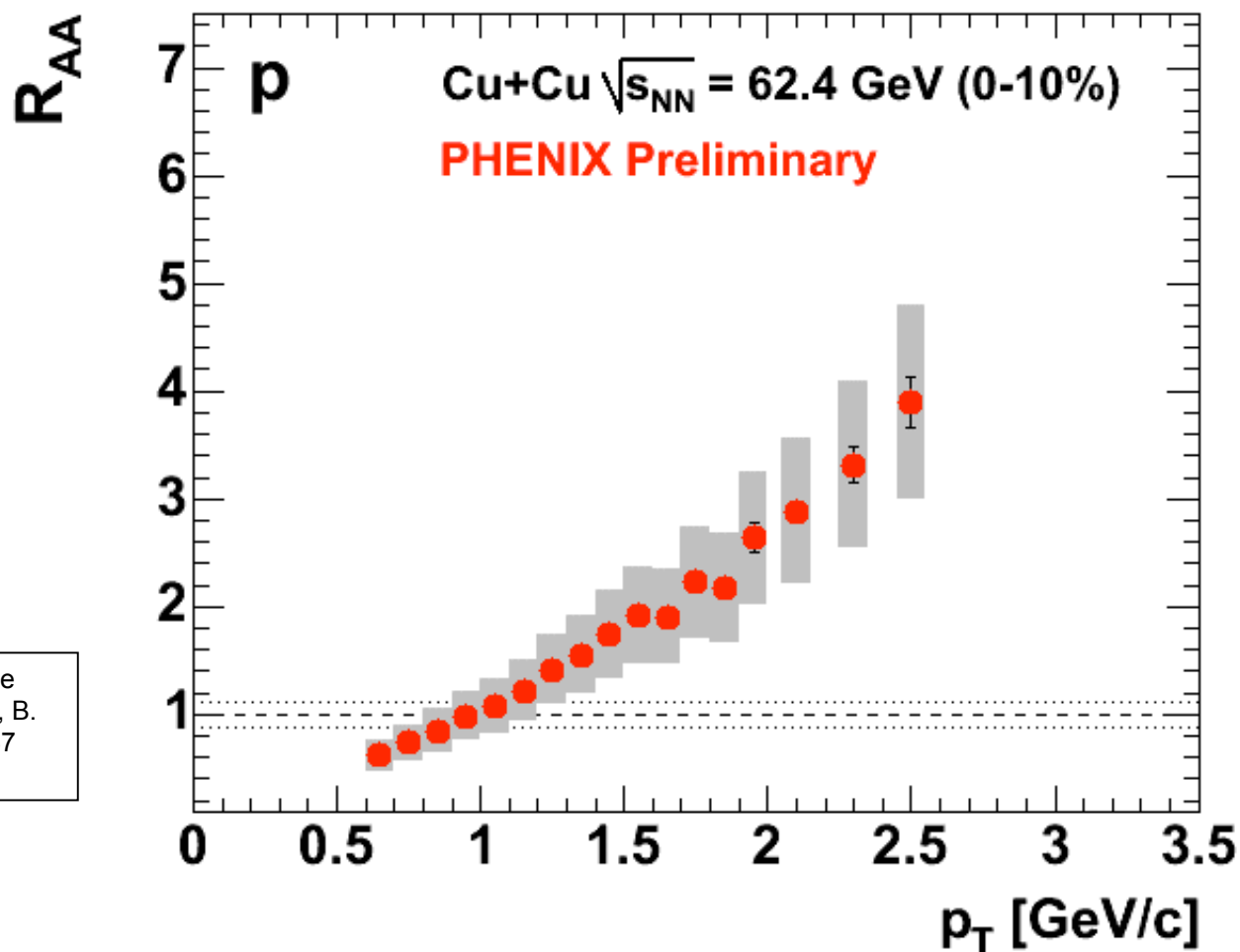
R_{AA} for proton (22 GeV)



• p+p reference: fitted the ISR data in p+p 63 GeV, B. Alper et al, NPB 100, 237 (1975).

- **Larger than pions significantly**, which suggests the large contributions of spectator protons.

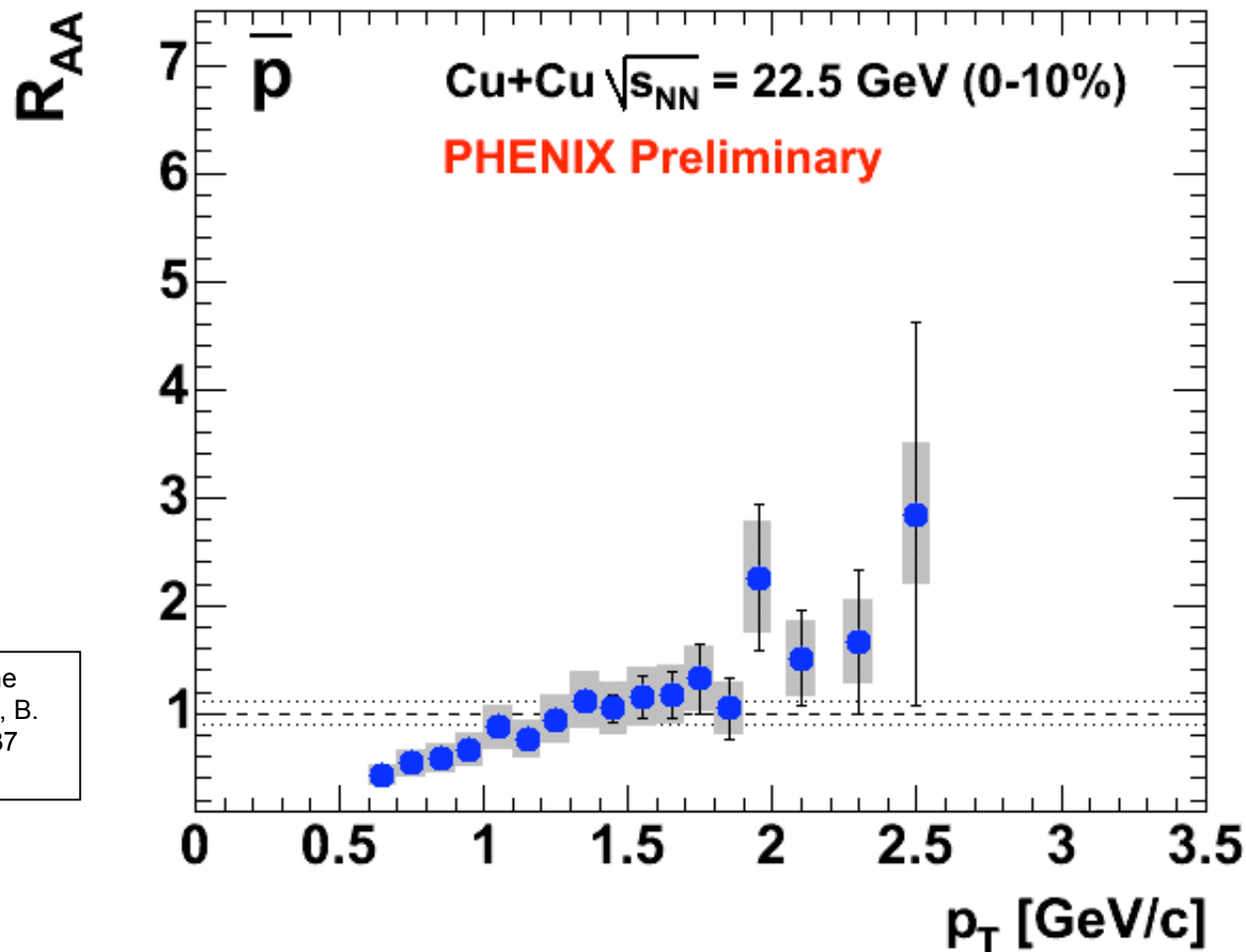
R_{AA} for proton (62 GeV)



• p+p reference: fitted the ISR data in p+p 63 GeV, B. Alper et al, NPB 100, 237 (1975).

• Similar as in 22.5 GeV, but slightly smaller value.

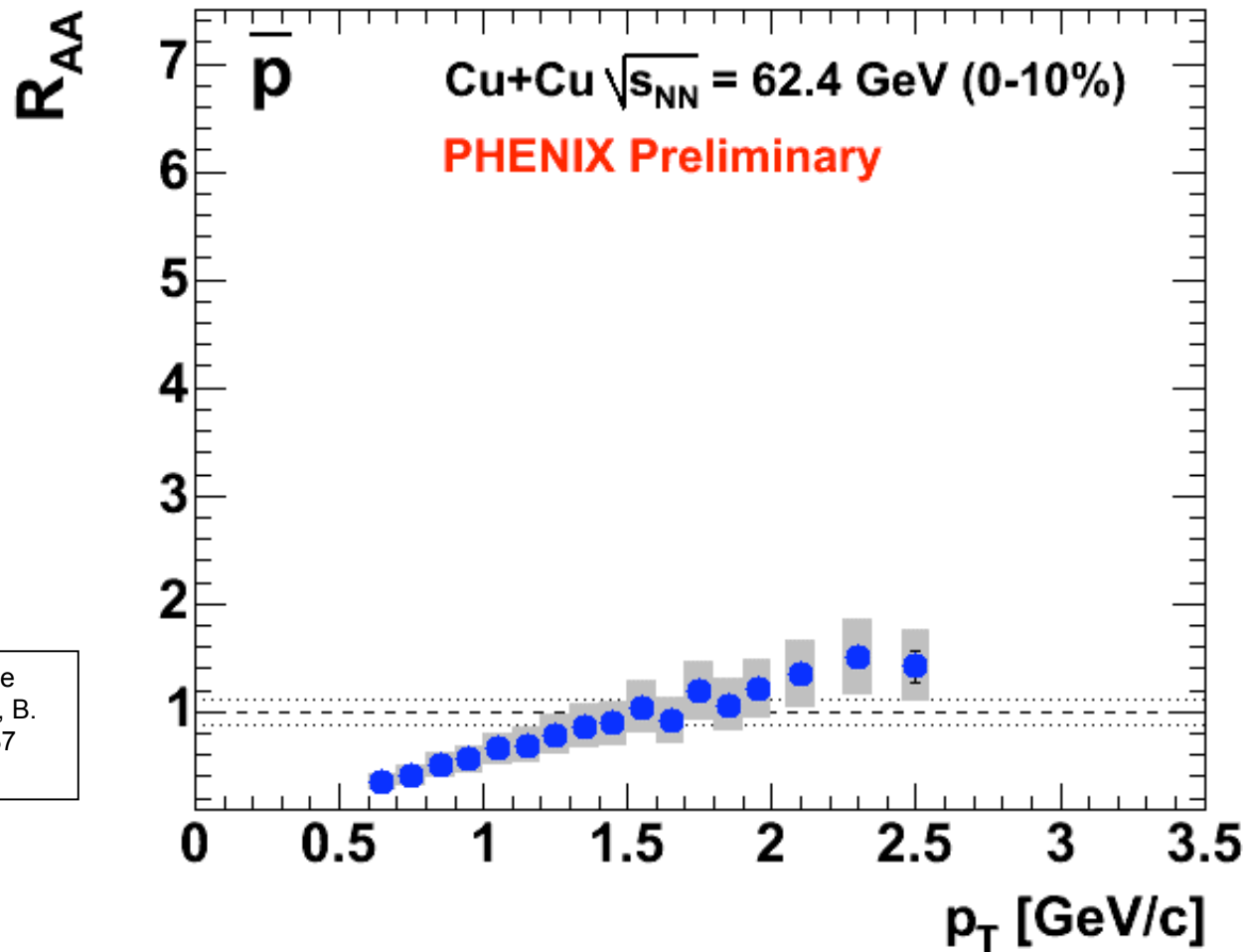
R_{AA} for antiproton (22 GeV)



• p+p reference: fitted the ISR data in p+p 63 GeV, B. Alper et al, NPB 100, 237 (1975).

- Different p_T dependence from protons.
- $R_{AA} \sim 1$ (similar to pions' R_{AA}), binary collision scaling worked?

R_{AA} for antiproton (62 GeV)



• p+p reference: fitted the ISR data in p+p 63 GeV, B. Alper et al, NPB 100, 237 (1975).

• Similar to that for 22 GeV (and also pion's R_{AA}).

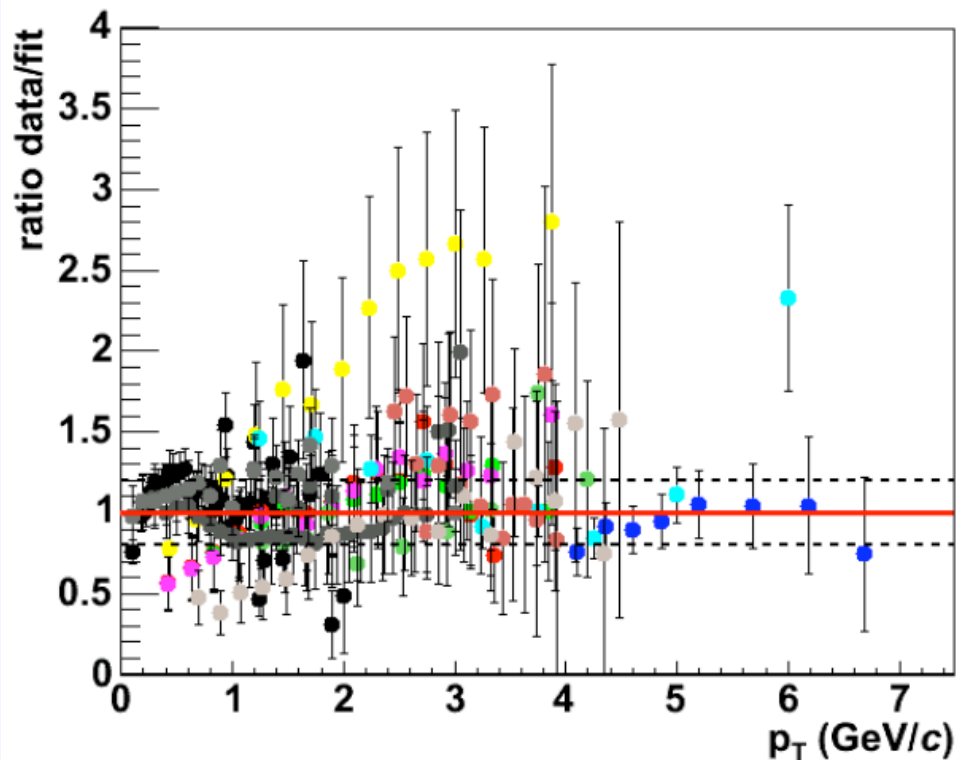
Summary

Measured p_T spectra for π^\pm , K^\pm , p , \bar{p} in Cu+Cu at $\sqrt{s_{NN}} = 22.5$ and 62.4 GeV in PHENIX.

- **p/π^+ ratio** : **decreasing** as a function of $\sqrt{s_{NN}}$ in Cu+Cu.
 - Suggests a significant contribution of spectator protons (not by the produced protons) in lower energies Cu+Cu.
- **\bar{p}/π^- ratio** : **increasing** as a function $\sqrt{s_{NN}}$ in Cu+Cu.
 - Cu+Cu 22.5 GeV shows that there is (almost) **no centrality dependence**, and central Cu+Cu already reaches to the p+p values.
 - Cu+Cu 62.4 GeV central data is higher than that in 22.5 GeV, centrality dependence is seen.
- **R_{AA}** :
 - Particle type dependent.
 - π : no suppression at both 22.5 and 62.4 GeV in Cu+Cu.
 - p : enhanced (mostly due to the spectator nucleons).
 - \bar{p} : binary scaling, very similar to pion's R_{AA} .

Backup Slides

p+p fit at $\sqrt{s} = 22.5$ GeV (pions)



p+p $\rightarrow \pi + X$ @ $\sqrt{s} \approx 22.5$ GeV

- p+p $\rightarrow \pi + X$ $\sqrt{s} = 21.7$ GeV -- EHS-NA22 [adamus88]
- p+p $\rightarrow \pi^0 + X$ $\sqrt{s} = 21.7$ GeV -- FNAL E-063 [carey76]
- p+p $\rightarrow \pi^0 + X$ $\sqrt{s} = 22.8$ GeV -- FNAL E-063 [carey76]
- p+p $\rightarrow \pi^0 + X$ $\sqrt{s} = 23.0$ GeV -- CERN-WA70 [bonesi89]
- p+p $\rightarrow \pi^0 + X$ $\sqrt{s} = 23.1$ GeV -- FNAL E-063 [carey76]
- p+p $\rightarrow \pi^0 + X$ $\sqrt{s} = 23.8$ GeV -- FNAL E-063 [carey76]
- p+p $\rightarrow \pi^0 + X$ $\sqrt{s} = 23.8$ GeV -- CERN-NA24 [demarzo87]
- p+p $\rightarrow \pi^0 + X$ $\sqrt{s} = 23.8$ GeV -- FNAL-E-268 [donaldson78]
- p+p $\rightarrow \pi^0 + X$ $\sqrt{s} = 23.3$ GeV -- R-107 [lloydowen80]
- p+p $\rightarrow \pi^0 + X$ $\sqrt{s} = 23.5$ GeV -- CCRS [busser76]
- p+p $\rightarrow \pi^0 + X$ $\sqrt{s} = 23$ GeV -- ACHM [eggert75]
- p+p $\rightarrow \pi^+ + X$ $\sqrt{s} = 23$ GeV -- Brit.-Scand.[alper75]
- p+p $\rightarrow \pi^- + X$ $\sqrt{s} = 23$ GeV -- Brit.-Scand.[alper75]

Compilation and fitting
by D. d'Enterria

R_{AA} for π^0 in Cu+Cu 22.5 GeV

PbSc (0-10%)

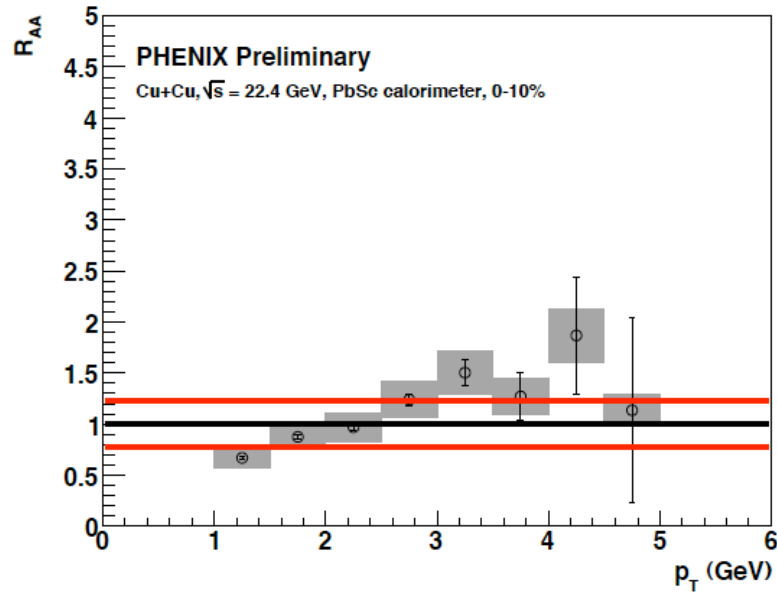


Figure 10: R_{AA} for the PbSc calorimeter and the Centrality Class 0-10%

PbGI (0-10%)

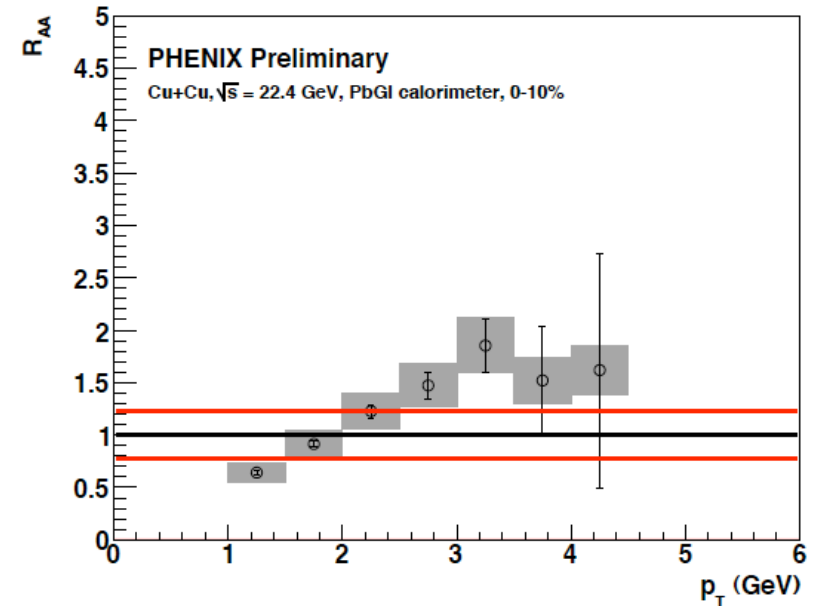


Figure 14: R_{AA} for the PbGI calorimeter and the Centrality Class 0-10%

SPS and AGS

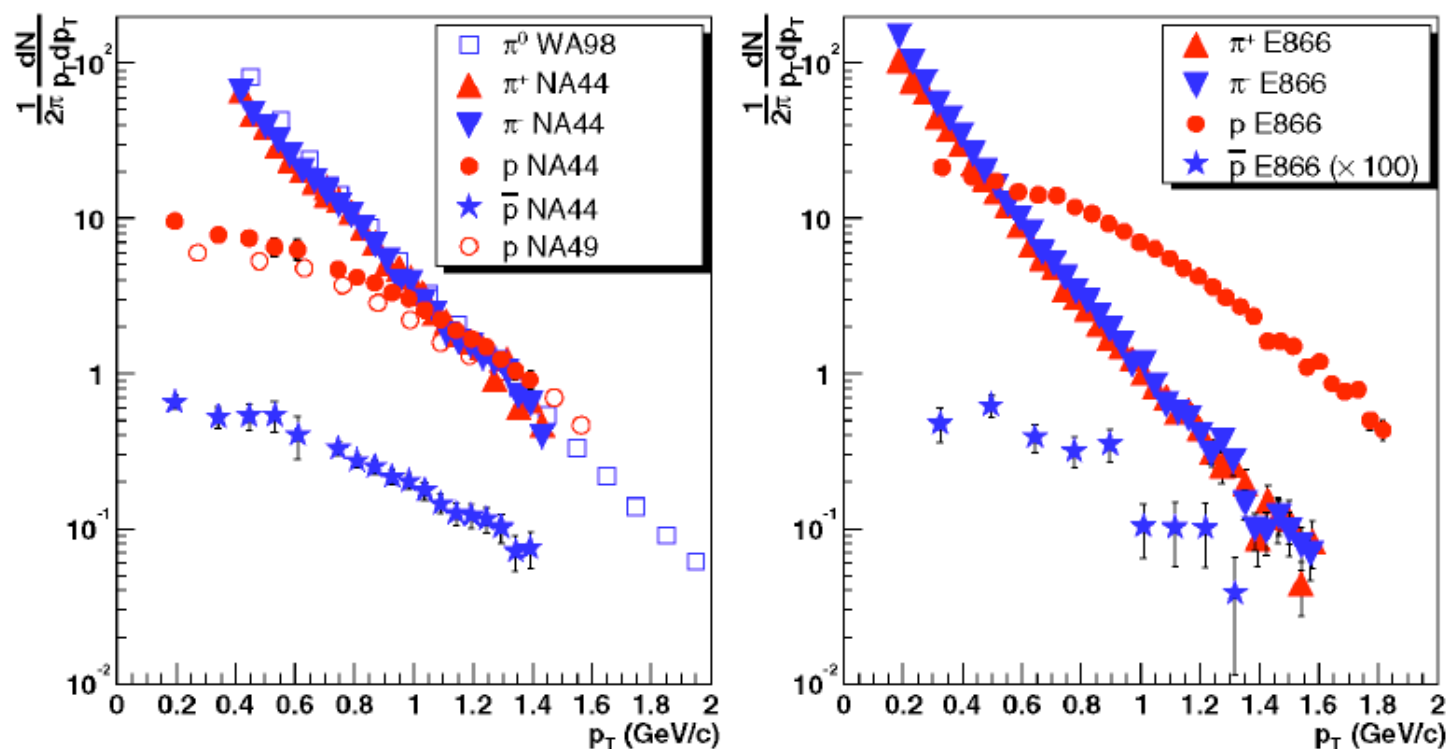


Fig. 47. Invariant yields of p , \bar{p} , and π as function of p_T in central Pb + Pb collisions at the SPS ($\sqrt{s_{NN}} = 17$ GeV) (left panel) and in central Au + Au collisions at the AGS ($\sqrt{s_{NN}} = 5$ GeV) (right panel). The \bar{p} spectrum from the AGS is scaled up by a factor 100. All data are at mid-rapidity ($y - y_{cm} \approx 0$) and are from W98 [163], NA44 [226], NA49 [227], and E866 [228,229].

Nucl. Phys. A 757, 184 (2005),
PHENIX, nucl-ex/0410003

NA49 data

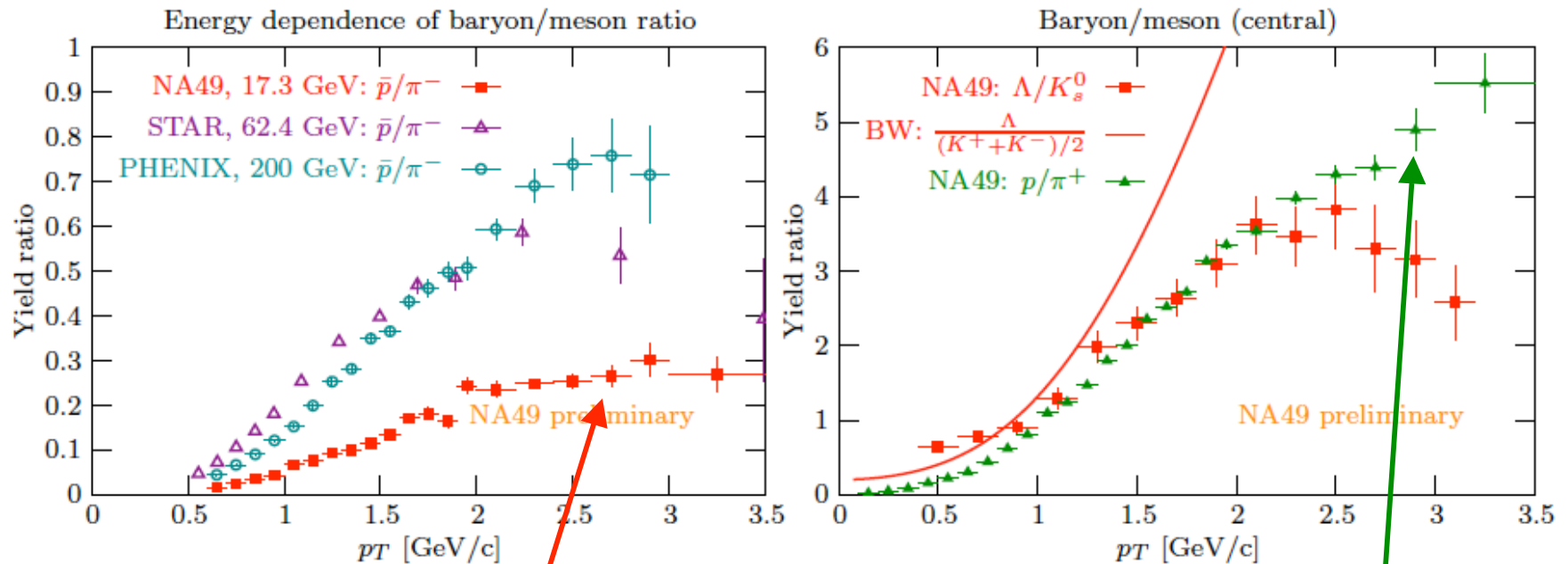


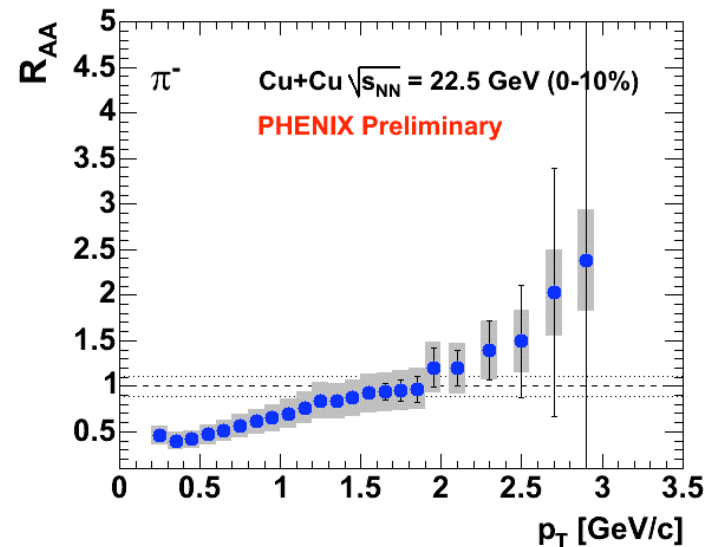
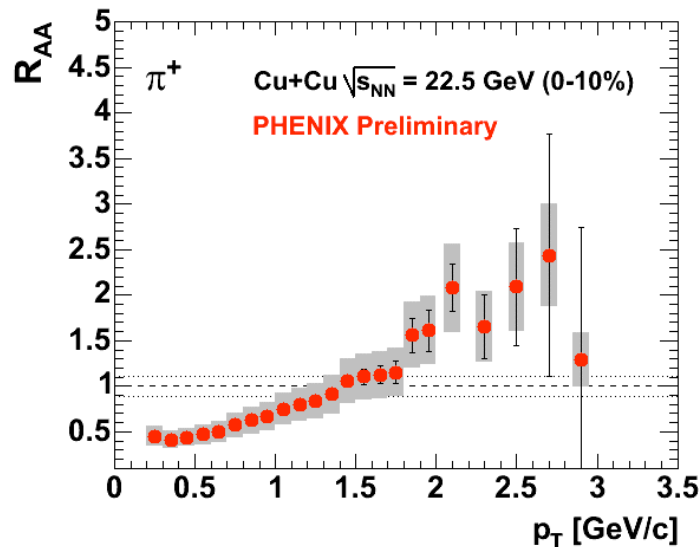
Figure 2. The energy dependence of proton/pion ratios (left panel), and a comparison of the baryon/meson ratios at top SPS energy to a Blast-Wave parametrization (right panel).

\bar{p}/π^- (NA49)

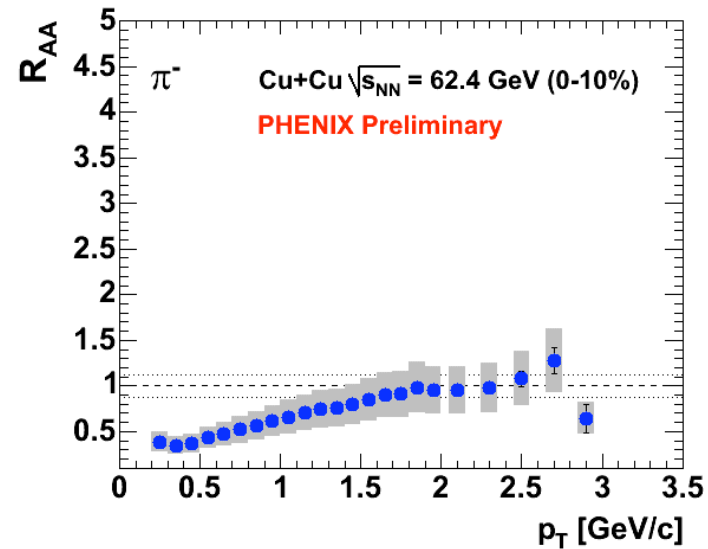
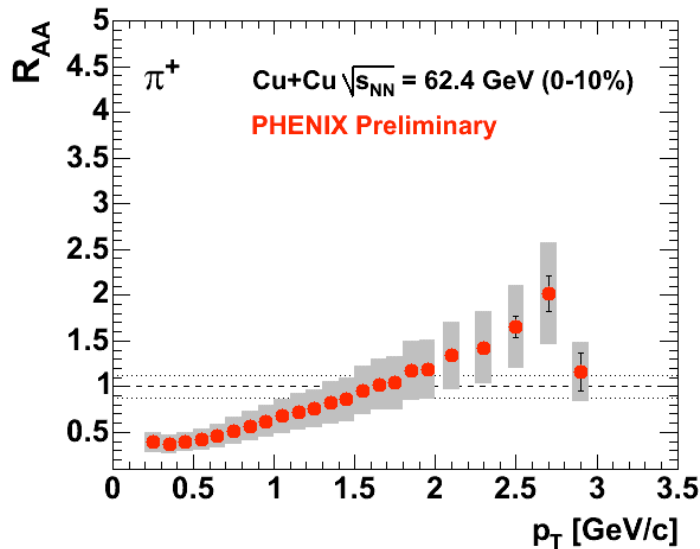
p/π^+ (NA49)

NA49 collaboration, nucl-ex/0510054

R_{AA} for pions

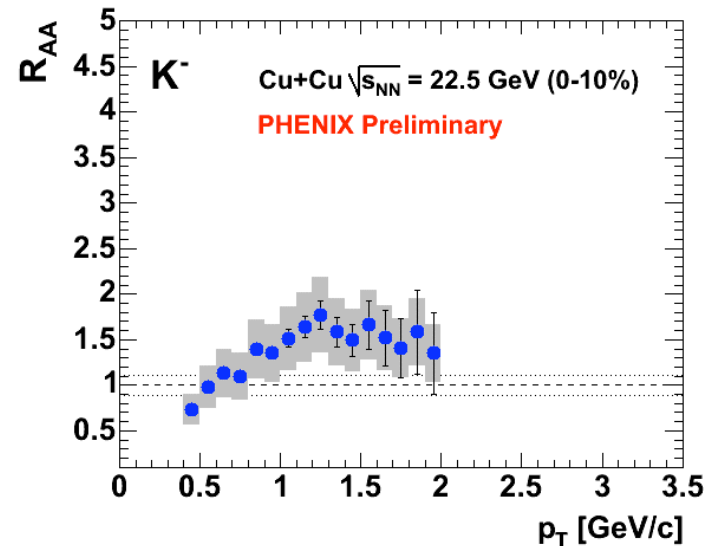
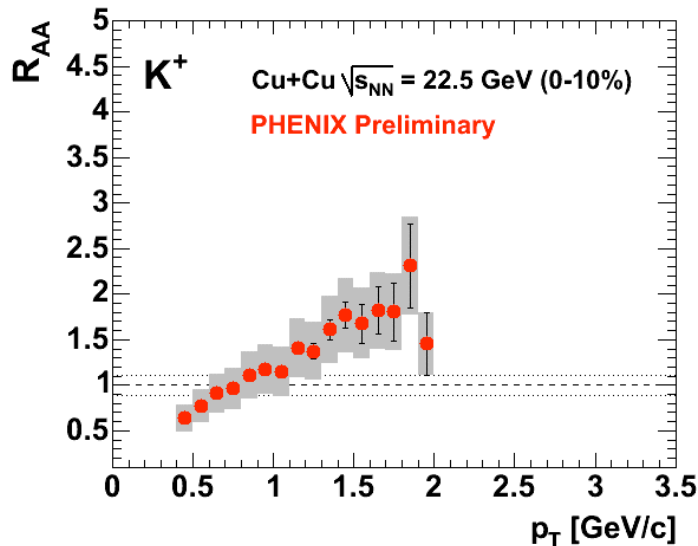


22.5 GeV

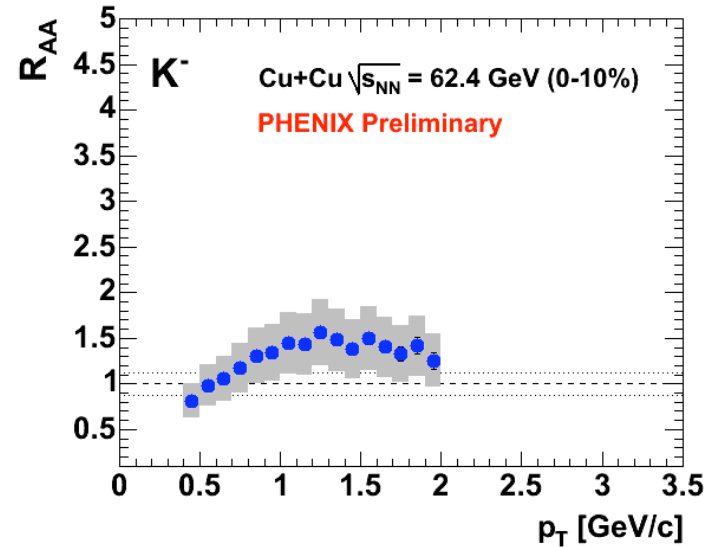
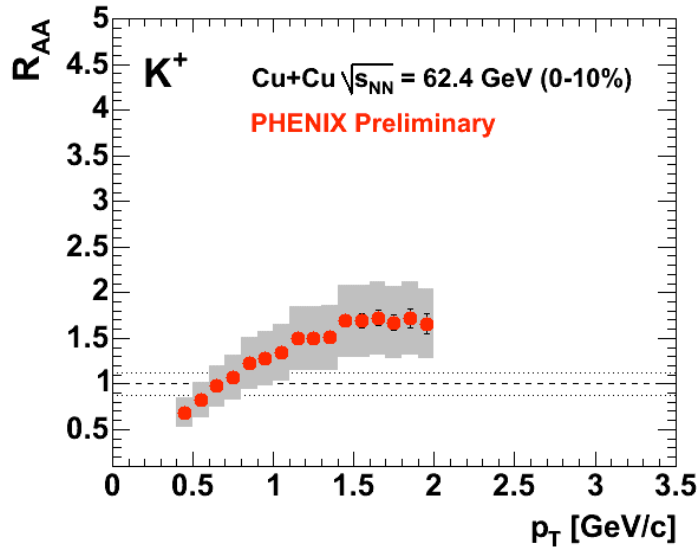


62.4 GeV

R_{AA} for kaons

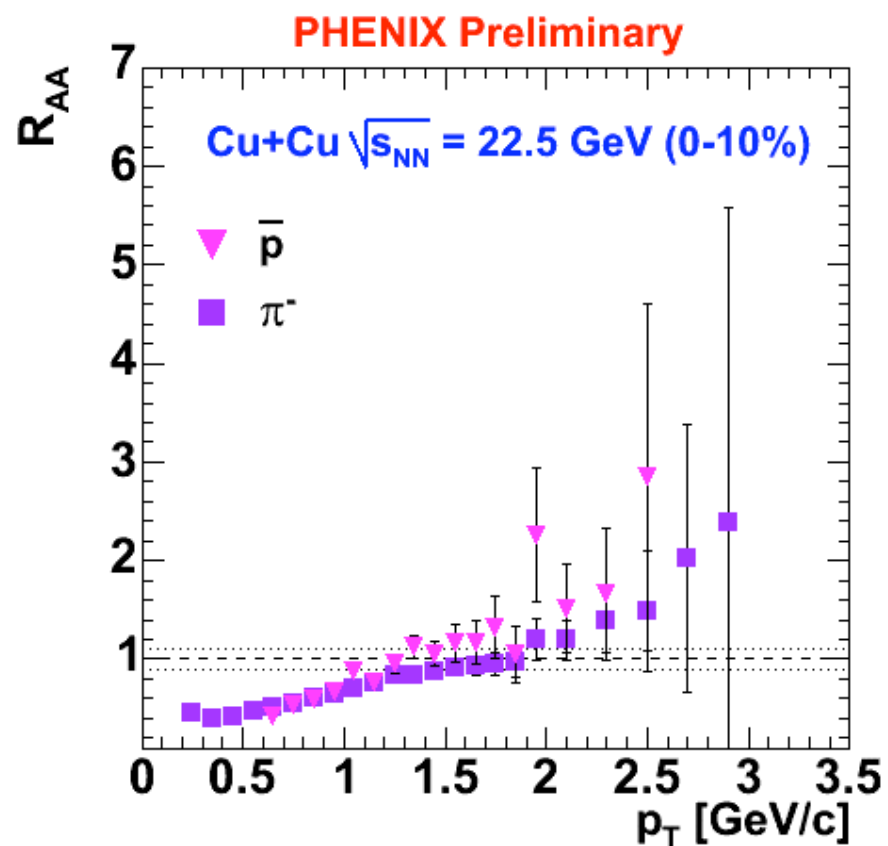
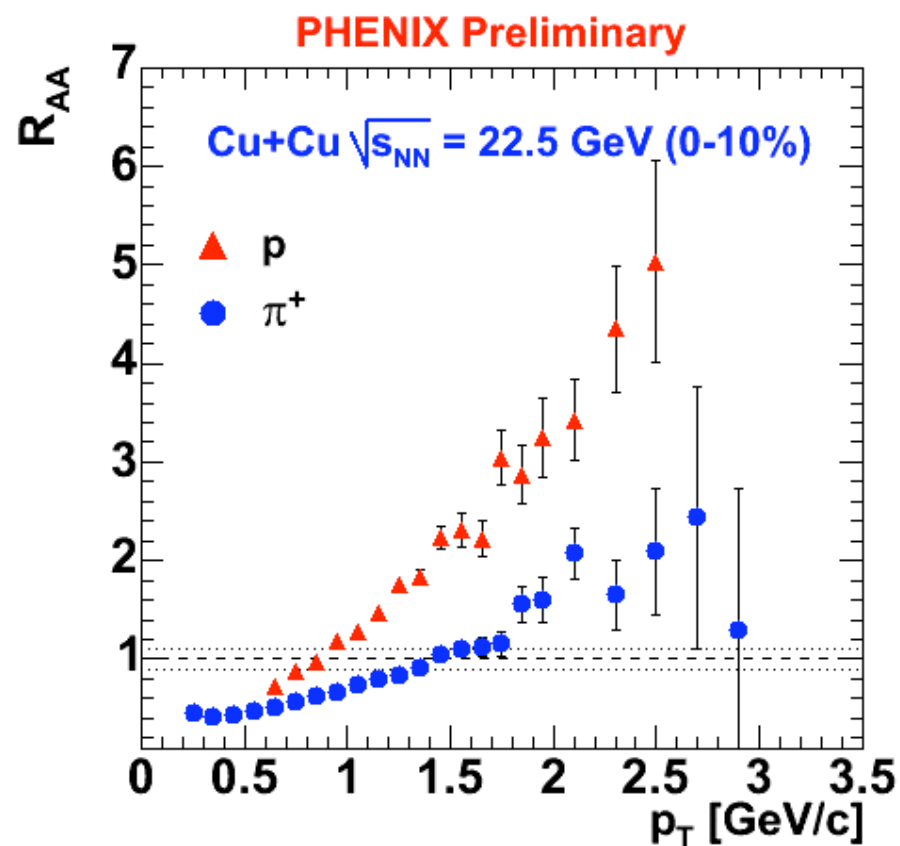


22.5 GeV

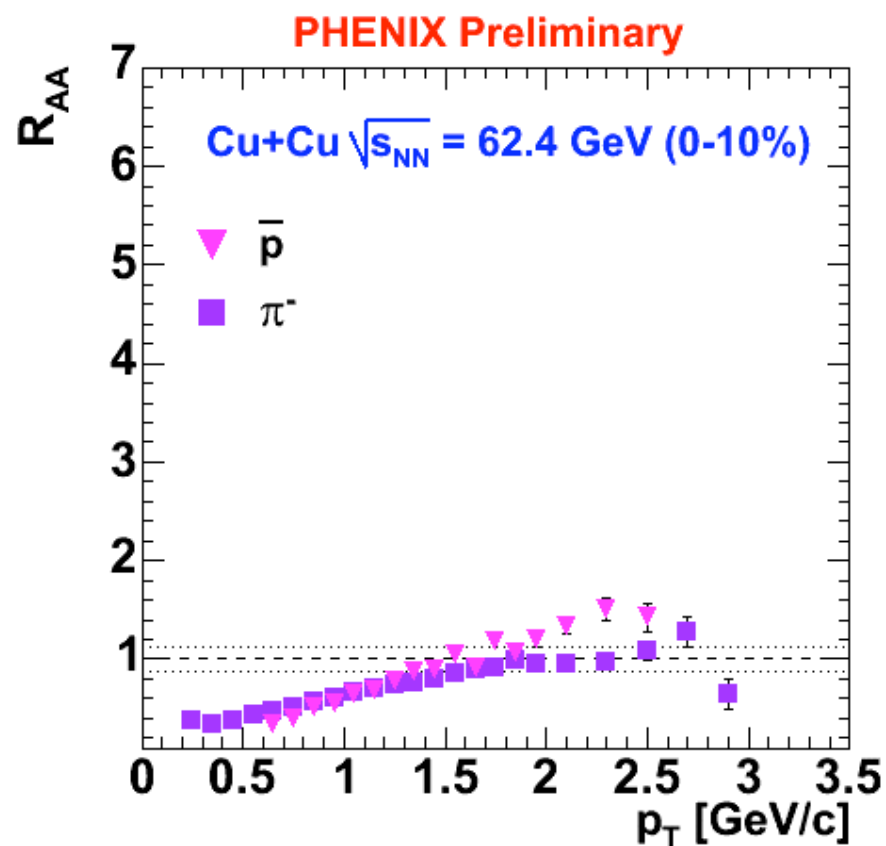
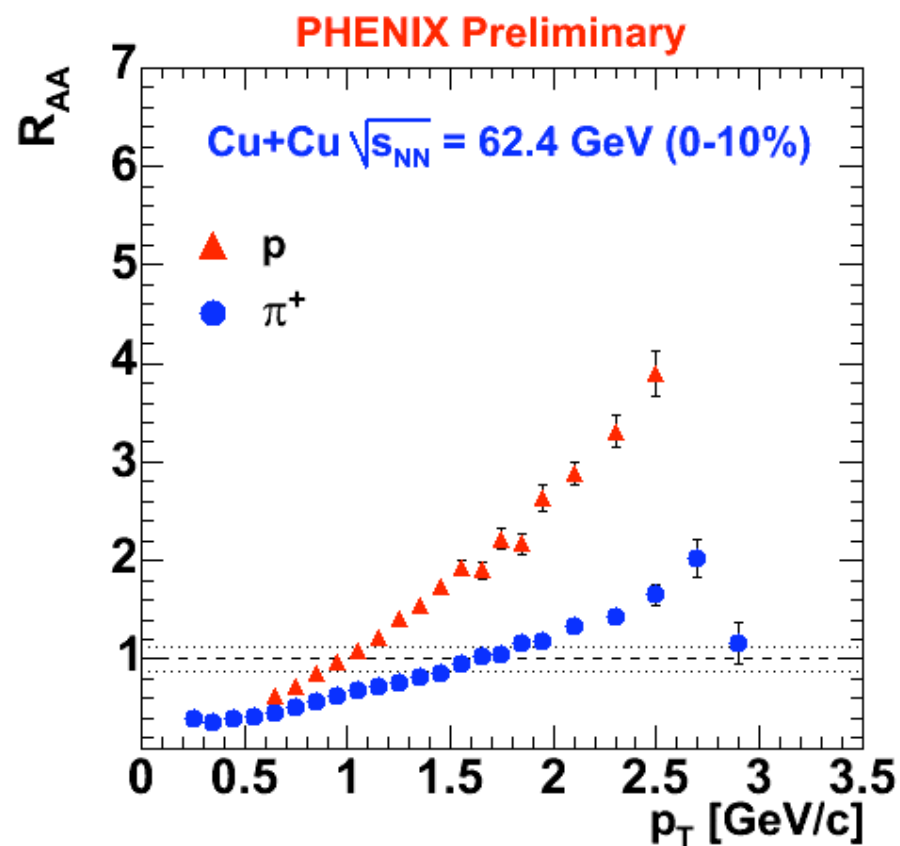


62.4 GeV

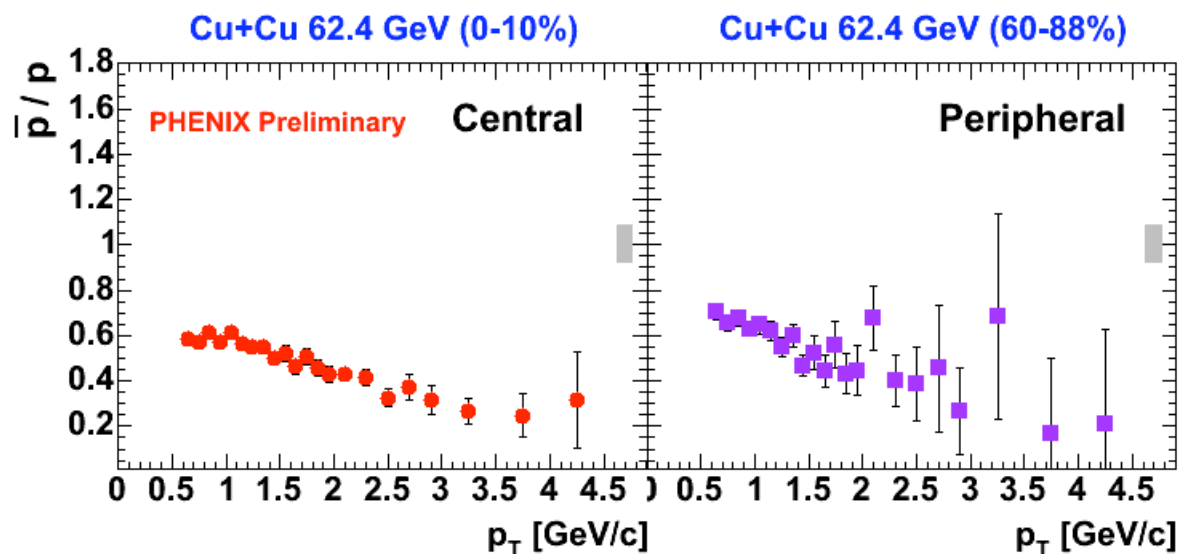
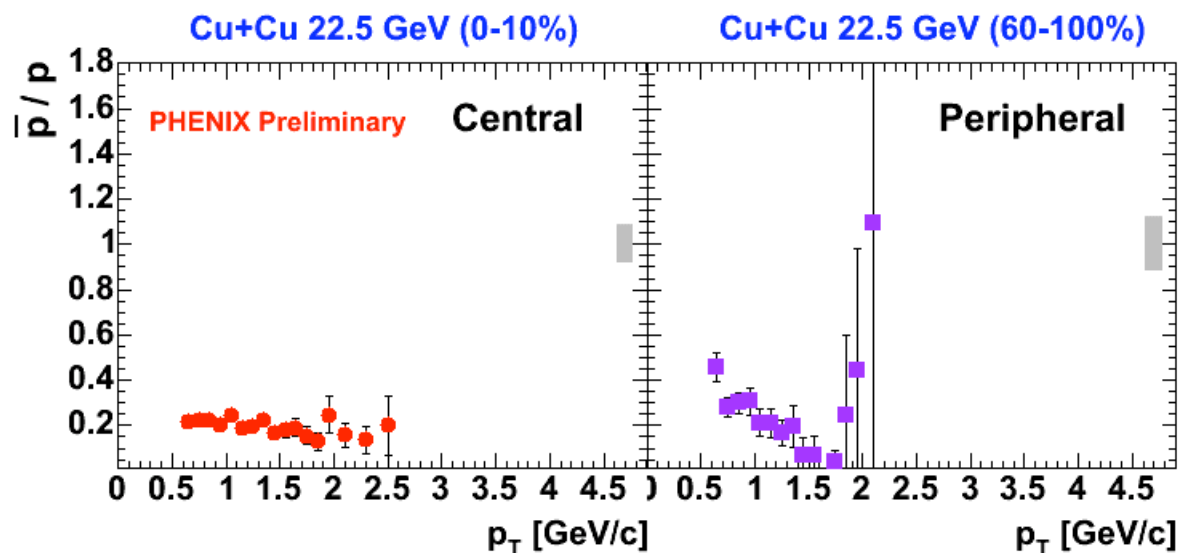
R_{AA} summary (22 GeV)



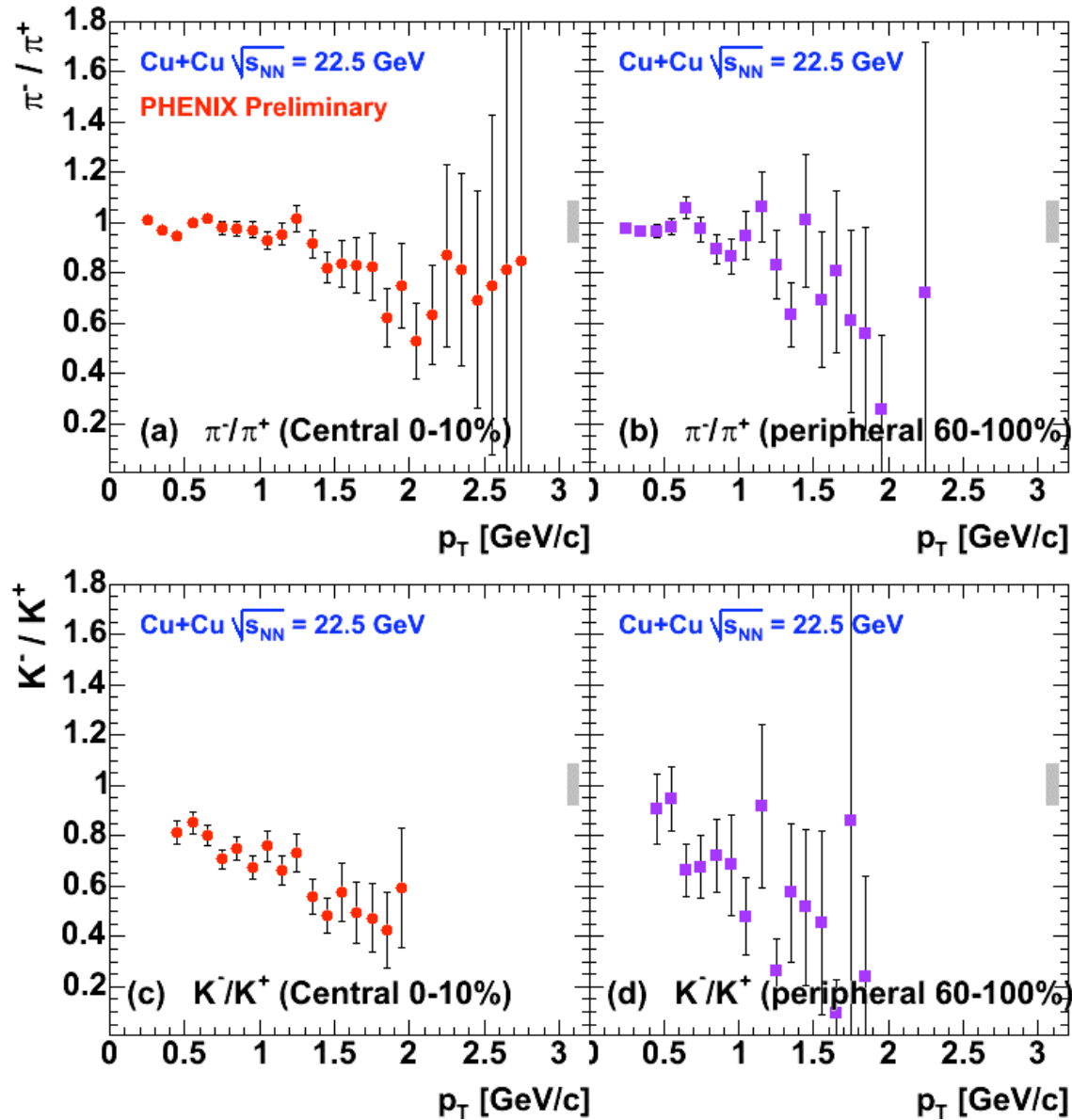
R_{AA} summary (62 GeV)



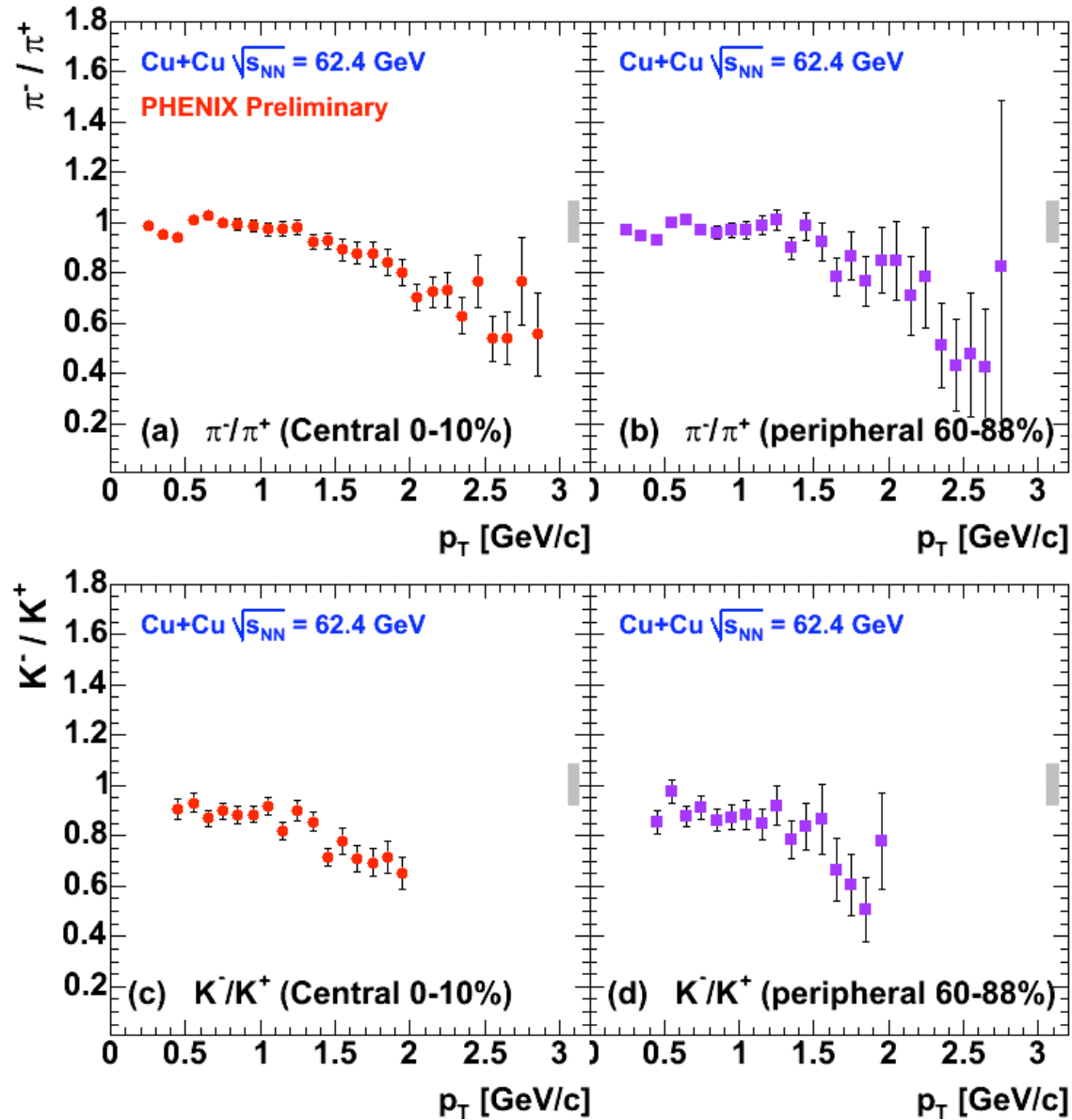
\bar{p}/p ratio vs. p_T



$\pi^-/\pi^+, K^-/K^+$ vs. p_T (22.5 GeV)



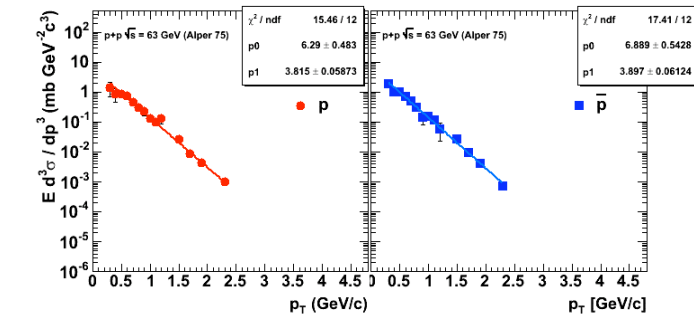
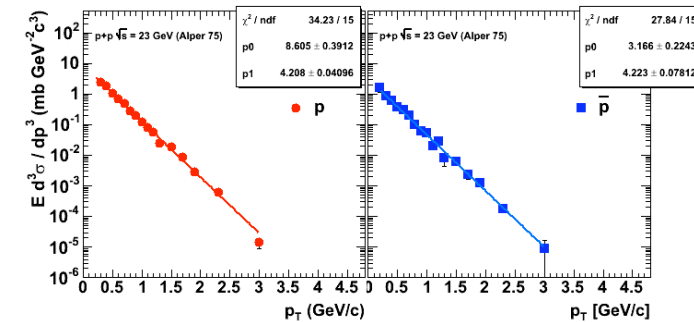
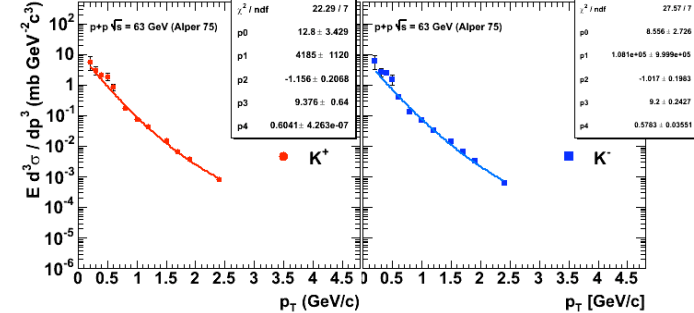
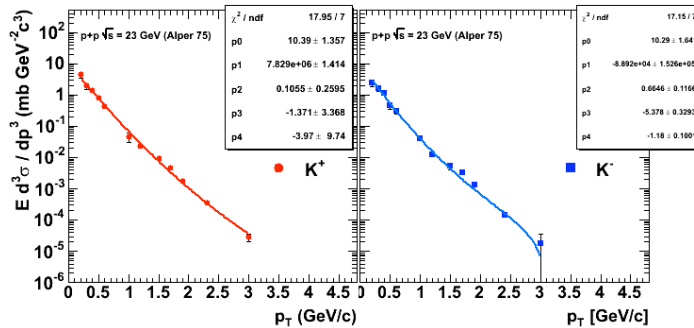
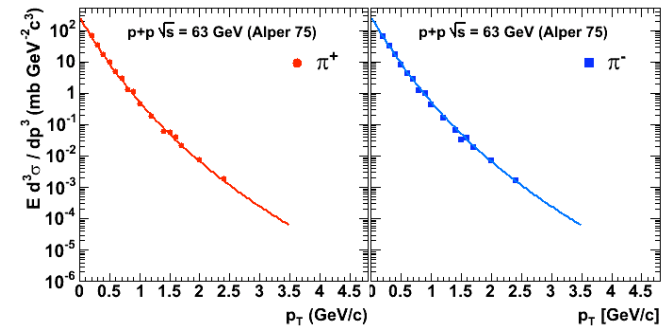
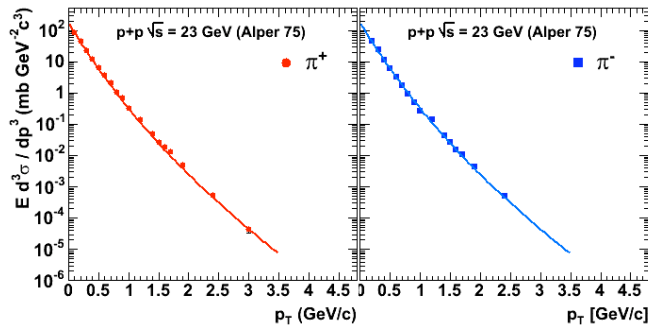
$\pi^-/\pi^+, K^-/K^+$ vs. p_T (62.4 GeV)



p+p reference data (with fit)

23 GeV

63 GeV



Kaons and protons: Fit results of ISR p+p 63 GeV data. B. Alper et al, NPB100(1975)237.
pions: global fits of p+p data, e.g. nucl-ex/0411049, D. d'Enterria.